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Baseline limnology and nutrient study of Basin Head Lagoon, Prince Edward Island, with management implications

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BASELINE LIMNOLOGY AND NUTRIENT STUDY OF BASIN HEAD LAGOON, P.E.I., WITH MANAGEMENT IMPLICATIONS

by

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ABSTRACT

Knowledge of physical and chemical process ongoing within an environment is an important step towards proper environmental management. Basin Head, Prince Edward Island is in the process of becoming a Marine Protected Area (MPA) and therefore a comprehensive management plan will need to be completed. The area contains a unique strain of Irish Moss (*Chrondrus crispus* Stackhouse) that is an important marine plant used in various industries. A study was conducted during the summer of 2000 to assess the basic physical and chemical conditions within the Basin Head Lagoon and surrounding stream inputs. The purpose of the study was to determine the impact, if any, that the surrounding streams have on the lagoon environment. The study examined rainfall, stream discharge, stream nutrients, and sediment loads, along with nutrient chemistry and bathymetry of the lagoon. Results were compared to a study conducted in 1979 to examine changes over the past 21 years. The results indicate that the streams do have an impact on the nutrient levels found within the lagoon. This is significant, as the nutrient levels found within the Basin Head Lagoon have been increasing over the years. Stream nutrient levels are higher than both the recommended concentrations suitable for freshwater environments and other freshwater systems around Prince Edward Island. Management within the watershed is necessary in order to decrease the levels of nutrients entering the lagoon. Some management strategies such as buffer zones and crop rotation have recently been implemented in the area. Future monitoring of the watershed is necessary to determine if these strategies will be enough to reduce stream nutrient concentrations.

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CHAPTER 1

1 Introduction

1.1 Problem Statement

Society is beginning to recognize the importance of our surrounding marine environments. These environments can have a variety of uses such as fishing, recreation, sources of water, or places for growth of marine fauna and flora. There is a growing population that is interested in protecting these marine environments for their many characteristics.

The problem that arises with the protection of these marine environments is the growing number of humans that inhabit the surrounding areas. The activities that occur after human settlement are bound to affect the surrounding environment. One particularly important activity in many coastal areas, and the Basin Head Lagoon is farming of the surrounding land. Clearing the land for agriculture causes increased risk of soil runoff, and addition of fertilizer to the land can potentially lead to increased levels of nutrients entering the surrounding marine environment. Designation of a Marine Protected Area is one way to protect marine environments from surrounding activity.

The Basin Head Lagoon has been designated a candidate for Marine Protected Area (MPA) status along with ten other areas within Canada. In June 1999 support for the designation of Marine Protected Area status for Basin Head was announced by the Solicitor General for Canada on behalf of the Minister of Fisheries and Oceans (Canada, 1999). A management plan will be developed with the Basin Head Lagoon Conservation

Committee, which will identify the actions required by both government and the community to provide long-term protection for the area.

> "A marine protected area as defined by the Oceans Act is an area of the sea that forms part of the internal waters of Canada, the territorial sea of Canada (12 nautical miles) or the exclusive economic zone of Canada (to 200 nautical miles); and has been designated for special protection under the Oceans Act for one or more purposes" (Fisheries and Oceans Canada, 1999).

The research conducted throughout this study was based on recommendations made by McCurdy (1979) in his study of the ecology of the Basin Head area. McCurdy (1979) suggested that knowledge of what enters the lagoon system in terms of sediment and nutrient input from nearby farmland would be valuable. The few studies in the Basin Head Lagoon area have looked at the Irish Moss within the lagoon, (Chopin, Sharp *et. al.*, 1999).

1.2 Objectives

The main objective of the project was to examine the impact, if any, the streams entering Basin Head Lagoon had on the nutrient levels found within it. This meant examining the levels of nutrients (phosphate, total phosphorus, nitrate, and nitrite) being exported from the Basin Head watershed, through surface runoff, into the Basin Head Lagoon. This would aid in understanding the effects of the surrounding agricultural areas on the watershed.

This information and knowledge of the lagoon system is necessary to complete a comprehensive management plan. Previous to this study little was known about the physical and chemical processes ongoing within the lagoon and in the freshwater, input streams.

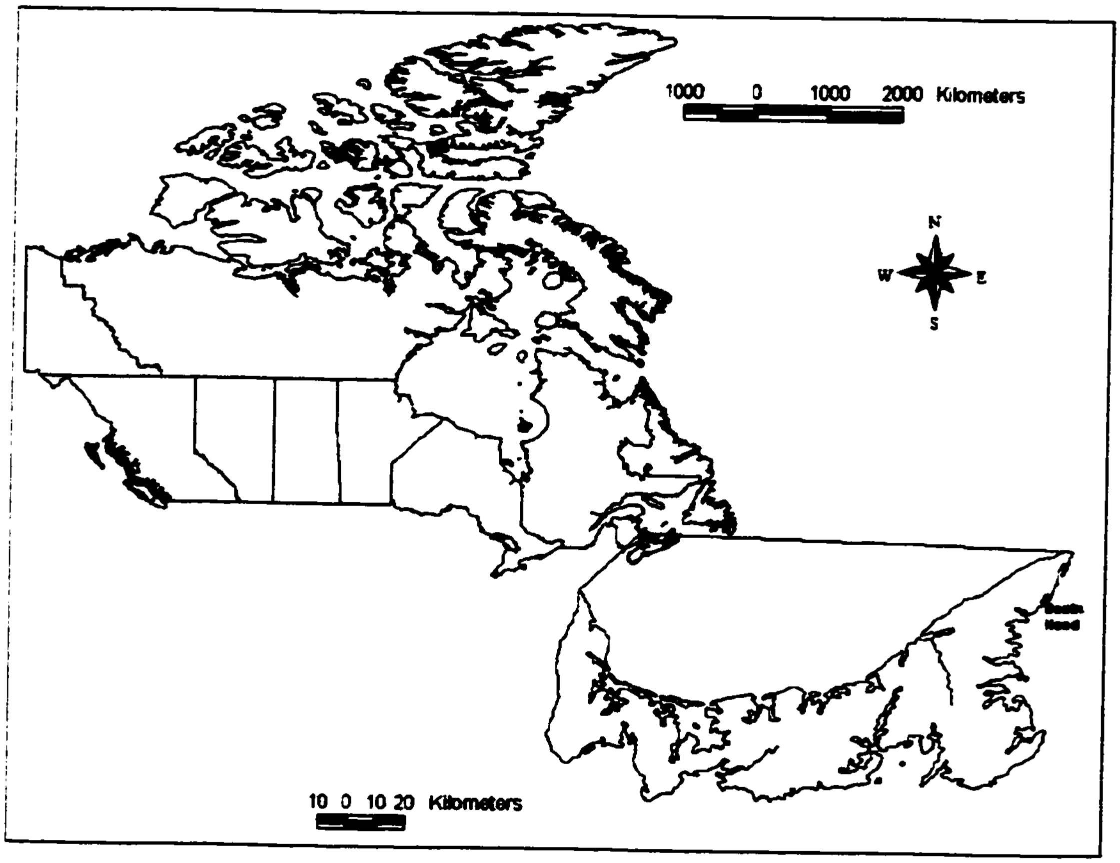
The study was also a means to obtain baseline information on the streams entering the lagoon. There had been no previous research in the area looking at stream inputs. Stream discharge, nutrient levels, and sediment loads were examined for three streams entering the lagoon.

The lagoon itself was also a part of the study in order to gain more information on its limnology. Nutrient levels throughout the lagoon were monitored and compared to the previous study (McCurdy, 1979). A basic bathymetric model of the lagoon was also produced to gain more knowledge of the physical environment.

1.3 Study Area and Methods

Basin Head Lagoon, located at the southeastern end of Prince Edward Island (Figure 1.1), has become an important marine environment in need of protection based on the presence of a unique species of Irish Moss (*Chrondrus crispus* Stackhouse). The area surrounding Basin Head is used primarily for agriculture. Soil erosion and subsequent deposits of sediment into streams and rivers is the largest environmental problem in Prince Edward Island (Day, 2000). It has been estimated that 14 – 30 tons of topsoil can be lost from each acre of land each year (Day, 2000; Environment Canada, 1996) and that agricultural activities account for most of this erosion (Environment Canada, 1996). The soil carries with it nutrients that can affect the surrounding marine environments. Therefore, knowledge of the inputs into the marine system from the surrounding watershed area is essential for the management of the Basin Head Lagoon.

This research on the Basin Head Lagoon monitored surface water inputs and levels of total phosphorus, phosphate, nitrate, and nitrite entering the lagoon through surface water runoff entering streams that drain the watershed area. Levels of suspended sediment in the stream were also examined. This was completed through water collection and monitoring of discharge. The study also examined nutrient levels throughout the lagoon for comparison with levels obtained in the 1979 study to determine what, if any, changes had occurred over time.



ArcView Sample Data, 1999

Figure 1.1 Location Map for Prince Edward Island, Canada

Water sampling took place during the summer of 2000 on a weekly basis. The samples were then analyzed at government laboratories for chemical composition. The analysis of suspended solids was completed at Wilfrid Laurier University. Bathymetric analysis was also completed at Wilfrid Laurier University. Time-series analysis was then completed to examine patterns in levels of nutrients and loads using Microsoft Excel.

1.4 Background

Studies on basic physical and chemical processes within lagoon environments have been ongoing for many years (Carpelan, 1969; Dronkers and Zimmerman, 1982; Groen, 1969; Smith and Atkinson, 1994; Spaulding, 1994). There have also been numerous studies looking at the links between agriculture and water quality (Heathwaite and Johnes, 1996; Johnes and Hodgkinson, 1998; Johnson and Treece, 1998; Jordan et al., 1997; Lapp et al., 1998; Lory, 1999; Meissner et al., 1999). Since the Basin Head Lagoon is in the process of becoming a Marine Protected Area the information on water quality and processes ongoing within the environment are necessary because it is very important knowledge in determining the appropriate protection strategies for the environment. The information collected can be used to give a better understanding of the processes of the environment. This knowledge will lead to implementation of the best management practices for the Basin Head Area.

The sampling program involved in the study was based on guidelines set forth by Environment Canada (1983). This helped maintain the quality assurance and control of the water collection stage.

Most studies that look at water quality in an agricultural area are conducted over a longer period of time, but due to constraints of time and funding, there could only be a sampling period of three months. Also, studies such as the one that examined watersheds of the Chesapeake Bay area (Jordan et al., 1997) were able to use automated samplers, which meant samples could be collected even when the researchers were not there. Jordan, et al. (1997) examined discharges of water, nutrients, and sediment from the streams. In this study they were dealing with relatively small streams of about 1-5m wide and less than 0.5m deep at base flow. Therefore mixing was assumed to be complete throughout the cross-section. The same is assumed in the Basin Head area. The study by Jordan et al. (1997) concluded that there were differences in nitrogen and phosphorus discharges related to land use and location within the coastal plain. This study was able to examine nutrient export with relation to land use during the same year. The Basin Head Lagoon study will be gathering this same information, but comparison with other nutrient levels can only be completed from information gathered in the lagoon from the McCurdy (1979) study. There have been no previous studies conducted on the streams within the Basin Head watershed, so the information collected will serve mainly as baseline information.

Kelly (1998) examined the role of ocean nutrient loading in Boston Harbour and concluded that it was necessary to include ocean nutrients in studies when examining coastal areas. The Basin Head Lagoon was highly influenced by the ocean and tidal movements therefore this examination was included for the study.

It is helpful to quantify the study area characteristics to other similar areas to identify similarities and differences. The environment of Prince Edward Island is very similar throughout. It is very low-lying, agriculture is abundant throughout and streams are very small leading to coastal estuaries and embayments. The report produced by Somers *et al.* (1999) looked at water quality around Prince Edward Island, both in freshwater streams and marine environments. The findings of this study will be compared to the Basin Head environment.

1.5 Outline

The following chapter will look further at the existing literature relevant to issues throughout the study. It will start by looking at common lagoon characteristics in order to give an introduction to the lagoon environment. The importance of protection of Irish Moss in the Basin Head Lagoon area will also be discussed. It will be succeeded by the sample collection literature used during the field component of the study. Most previous studies in the literature on water sampling were designed to use automated sampling techniques and were for longer periods of time, therefore knowledge of the conventional methods of water sampling were very important for the study. Suspended solids in the stream environment will also be discussed. The bathymetry is a very important part of the physical status of the lagoon. The literature review will also include information on bathymetry mapping that was used as a guideline for the project. The literature review will then look at the numerous resources on phosphorus and nitrogen in the agricultural environment. For the most part, the abundant nutrients in an agricultural environment are phosphorus and nitrogen and are therefore the most susceptible to runoff from the fields to the surrounding waters. Freshwater stream chemistry as well as lagoon chemistry literature will be reviewed. Affects of land use change literature will also be noted as relevant to changes from the previous study conducted by McCurdy (1979) and the current project. A comprehensive management plan will be a necessary component of the Basin Head area when it is designated a Marine Protected Area. Therefore, the final component of the literature review will examine management practices in an agricultural area in order to reduce runoff of nutrients to surrounding waters.

The remaining material in subsequent chapters will look at the methods used throughout the study from data collection to the analysis. Another chapter will be dedicated to examining the results of the findings and will include a discussion of what these results mean for the Basin Head area. The final chapter will give conclusions of the study and report any recommendations for further study.

CHAPTER 2

2 Literature Review

2.1 Introduction

The lagoon environment is a very dynamic one and individual characteristics are unique for each. "The understanding of physical, chemical, geological, and ecological dynamics of a lagoon is important for planning and implementation of coastal management strategies in coastal lagoons" (Kjerfve, 1994; 4). The study conducted during the summer of 2000 examined mainly the chemical and physical properties of the environment. Geologic and ecological conditions at Basin Head have been previously assessed by different studies (Chopin, 1999; Griffin, 1973; McCurdy, 1979; Palmer, 1978). The stream inputs to the lagoon were included in this study as they are seen as an important means for nutrient transport from the agricultural land surrounding the lagoon. The following literature review will examine basic lagoon characteristics, Irish Moss (*Chondrus crispus* Stackhouse) ecology, sample collection methods, suspended solids, bathymetry, phosphorus and nitrogen in agricultural environments, freshwater stream chemistry, lagoon chemistry, land use change effects, and management.

2.2 Lagoon Characteristics

There are many different ways to define a lagoon. Each lagoon is a very individual and unique body of water. Phleger (1969) gave a definition of coastal lagoons as "an inland water body, usually oriented parallel to the coast, separated from the ocean by a barrier, connected to the ocean by one or more restricted inlets". To this Kjerfve (1994) added "the ocean entrances can at times be closed off by sediment deposition and that their depths seldom exceed a couple of meters". Also, he noted that there may or may not be tidal mixing and salinity levels may vary. The definition that will be used throughout the study are the ones given above. This view closely resembles the situation found in Basin Head Lagoon, where there appears to be complete tidal mixing, and depending on tidal level salinities vary.

Salinity, water quality, and eutrophication depend on lagoon circulation, salt and material dispersion, and water exchange through inlets and flushing times (Kjerfve, 1994). Therefore in order to properly manage a coastal lagoon environment there must be knowledge of physical, chemical, and ecological dynamics of the lagoon. This study will focus on the basic physical and chemical properties of the lagoon. Salinity levels give rise to as many as four types of environments within lagoons, the freshwater dominated zone, brackish zone, sea-water dominated zone, and hyperhaline zone. In the Basin Head Lagoon the freshwater input is very limited, therefore most of the area is representative of brackish and sea-water dominated zones. The shallow depth of lagoons is also a very important part of the environment. The bed of a lagoon is usually formed of soft muds because of the deposition of fine sediments in sheltered conditions. Wind can also have an effect during strong conditions in resuspension of fine sediments causing turbid waters.

It is important to remember ocean contributions of nutrients to lagoon environments can be an important source. The traditional 'watershed as a source' that dominates coastal management must also include the connection between shallow inshore waters and the adjacent ocean waters (Kelly, 1998). Phosphate concentrations within marine waters should average approximately 20μg/l (Bowen, 1979). There have been no Canadian guidelines set for critical nutrient levels within lagoon environments.

2.3 Irish Moss

The Basin Head Lagoon contains a unique type of seaweed called Irish Moss (*Chondrus crispus* Stackhouse). It is the main reason behind the lagoon becoming a Marine Protected Area. The Irish Moss at Basin Head is unique in that it is much larger than common Irish Moss, is free-floating instead of being anchored, contains only one, asexual, reproductive phase while the common variety can reproduce both sexually and asexually, and is higher in carrageenan content than the common variety. Because of these unique characteristics there have been studies conducted to try open-water aquaculture of the Basin Head Lagoon Irish Moss (Chopin *et al.*, 1999; Gallant, 1988). Irish moss is a very commercially important marine plant from which carrageenans are extracted and used in various industries (agro-foods, pharmaceuticals, and cosmetics) for their specific physical and chemical properties (Chopin, 1986; Ffrench, 1970). The strain of Irish Moss found at Basin Head is 50 % more valuable than the common variety because it yields 50% more carrageenan. Research conducted by Glyn Sharp, Department of Fisheries and Oceans, on cultivating this unique strain of Irish Moss has been ongoing since 1989 (Fisheries and Oceans Canada, 2001). Levels of nitrogen and phosphorus found in the tissue of Basin Head Irish Moss was examined previously by Chopin *et al.* (1999) from May to October 1997. Levels of tissue total P content in June, July and August were 2.5, 3.2, and 3.2 (mg P. g DW^{-1}) respectively, where DW stands for dry weight. Levels of total N content for the same time period were 34, 30, and 25 (mg N. g DW^{-1}) respectively.

2.4 Sample Collection

Lagoon water quality studies should monitor the amount and source of surface fresh water entering the lagoon environment (Miller and Smith, 1990). There have been no previous studies of fresh water inputs at Basin Head. There are many different water quality sampling strategies. Some of these include fixed period sampling such as monthly, semi-monthly, and every six weeks. Some strategies also include more frequent sampling during storms or peak flow. This sampling is most often conducted using automated samplers, depending on financial capabilities. The type of sampling conducted is dependant on the duration of the study, the type of information needed, and most important the sampling budget. Because of financial constraints the number of samples that are collected and analyzed is often limited. The goal for sampling using the integration approach is to define all of the changes in concentration for the stream. Therefore sampling for the integration approach is usually designed to collect samples sparsely when concentrations are thought to be stable and more often when concentrations are thought to be changing, such as during rainfall (Robertson and Roerish, 1999). For the Basin Head study samples were taken weekly with additional sampling taking place during days of adequate rainfall.

The most essential hydrologic measurement of a stream ecosystem is discharge (Gore, 1996), the volume of water flowing through a cross section of a stream channel per unit time. There are different methods used to calculate discharge such as discharge from velocity, weirs, and flumes. Discharge is equal to velocity of the stream flow multiplied by the cross-sectional area through which the flow occurs. Direct measurements of velocity can be made using a current-velocity meter or the float method. The float method involves a floating object being dropped in the stream and timed as it travels a given distance. A weir is a structure built into a stream that forces water to flow through an opening of known shape. Discharge can be calculated by measuring the height of water flowing through the opening. The opening can be constructed in many different ways but V-shaped notches are better for measuring small changes in flow (Sanders, 1998). The calculation used to determine discharge in a 90° V-notched weir is as follows:

$$Q = 1.343H^{5/2}$$

Q = discharge, m^3/sec and H = head of the water above the apex of the V-notch, m (Sanders, 1998). A flume is similar to a weir except that the water flows through a channel of known dimensions instead of a two-dimensional opening.

2.5 Suspended Solids

Sediment, the product of erosion, is widely regarded as the major pollutant entering our streams, lakes, and estuaries (Carpenter *et al.*, 1998; Day, 2000; Skaggs et al., 1994). The mass of sediment far exceeds that of any other pollutant, and it is clearly the single biggest pollutant from agricultural lands, as well as from other sources such as construction sites, mining, and logging operations (Skaggs et al., 1994). Globally, more nutrients are added as fertilizers than are removed as produce, therefore leaving nutrients in the soil to be transported to nearby river systems (Carpenter *et al.*, 1998). Suspended solids are important vectors for the transport of nutrients and contaminants in river systems (Droppo and Ongley, 1992). There are losses of dissolved phosphorus to river systems through runoff, but even more phosphorus is transported as particles. The effects of dissolved phosphorus can be seen immediately but particulate phosphorus can become available to the aquatic biota in the long term (Sharpley *et al.*, 1994). Therefore, it is important when dealing with nutrient studies in an agricultural area to include information on suspended sediment being transported by streams to the water body in question. Grab samples are considered an appropriate method for obtaining suspended solid samples when the streams are relatively shallow and well mixed (Beschta, 1996).

Conrad (1999) examined fluvial suspended sediment yields from eastern North America. The data included 6 rivers throughout Prince Edward Island during the 1970s to late 80s. The mean sediment yield for the 6 rivers in Prince Edward Island was 22.2 t km^{-2} a^{-1}, which was the second highest for the maritime provinces (Conrad, 1999). An article published in *The Guardian* (Day, 2000) reports the problems of soil erosion throughout Prince Edward Island where agriculture is dominant. The article states that it is not unusual to see 20-30 tons per acre of topsoil eroded from agricultural fields on Prince Edward Island each year. Environment Canada (1996) stated that PEI farmland loses about 14 tons of topsoil every year.

2.6 Bathymetry

The study of any coastal water body has a basic requirement of an adequate map of the bathymetry (Wright, 1974). A bathymetric map is defined as a map that shows the depth of the body of water and its measurement. A bathyorographical map is one showing depths of water above the floor using lines of equal depth (Whittow, 1984). Most bathymetric maps are produced using a geographic information system (GIS). This makes it easier to handle all of the raw depth measurement data and makes mapping easier and faster. Using a GIS also allows easier integration of other data for future studies. The GIS provides researchers and policymakers a view of the relationship among data sets to assist studies and to help with economic and social policy-making decisions regarding the protected environment (Wong and Eittreim, 2001). The current study was only interested in providing the bathymetric map, but GIS could be a very useful tool in the future for mapping other relationships such as growth areas of Irish Moss.

The bathymetry map that was produced was used to assess the hydrologic residence time (or flushing time) of the Basin Head Lagoon. Flushing time is defined as the time required for freshwater inflow to equal the amount of freshwater originally present (Alber and Sheldon, 1999; Miller and McPherson, 1991). The flushing time concept is a useful tool for coastal marine management. The fraction of fresh water method as described by Dyer (1973) is used to determine flushing time. The method uses information about lagoon bathymetry (volume), salinity distribution both inside and outside the lagoon, and river discharge rates. The following equations were used to attain residence time:

$$R + V_{in} = V_{out}$$

$$V_{out} = R/\left\{1-\frac{S_{in}}{S_{out}}\right\}$$

And,

$$V_{in} = V_{out}\,\frac{S_{in}}{S_{out}}$$

Where, R = Stream Discharge Rate, V_{in} = Inflow Amount, V_{out} = Outflow Amount, S_{out} = Ocean Salinity Levels, and S_{in} = Lagoon Salinity Levels. Solving for V_{out} and V_{in} gives amounts in m^3/sec for the amounts flowing in and out of the system. To attain a time value for residence the following equation was used:

$$\text{Time (Days)} = \frac{\text{Volume}}{V_{in}}$$

(B.Petrie,personal communication, March 15, 2002)

The volume used is during low tide to obtain a standard residence time. Using high tide volume one can calculate the longest residence time expected. This method was used as it is the one used by Fisheries and Oceans Canada to calculate residence time for other lagoons and estuaries around Atlantic Canada. This method is only an estimation as the freshwater discharge should include the sum of the surface runoff, groundwater seepage, and direct precipitation, less a correction for evaporation (Miller *et al.*, 1990). No attempt is made to understand the dynamics of the circulation or the details of the diffusion process (Bowden, 1967). This method uses only volume, salinity distribution, and river discharge rate to obtain a flushing time (Tomczak, 2000). The derived flushing time is only a very basic description of the flushing process (Tomczak, 2000).

2.7 Phosphorus & Nitrogen in Agricultural Environments

Chemical inputs to rivers, lakes, and oceans are classified as point or nonpoint sources (Carpenter et al. 1998; Daniel et al. 1998; Sharpley et al. 1995). Point sources have, in the past, been given more attention in research due to the fact that they are easily identifiable. These sources include such things as sewage treatment plants, industrial plants, runoff from mines, and storm sewer outfalls from some cities. Since these sources are easily identified, monitoring and regulating of pollution are relatively simple as compared to nonpoint sources. Nonpoint sources include runoff from agricultural, pasture and range fields, atmospheric deposition, and activities on land that generate contaminants such as construction and development. Nonpoint inputs have become the major source of water pollution because they are difficult to measure and regulate and, therefore, are often overlooked as a means to reduce pollution to receiving waters.

Runoff from agricultural land is one of the major sources of non-point source pollution (Daniel et al., 1998).

Phosphorus and nitrogen loading of surface waters has been a well recognized cause of aquatic ecosystem degradation. Phosphorus is widely accepted as being hazardous to aquatic ecosystems when concentrations exceed values as low as 10 μg P/l (Correll, 1998). These nutrients enter the surrounding waters in many ways but this study will focus only on surface water transport of nutrients. Land use is well known for its influence on nutrient levels in aquatic ecosystems, especially where agriculture has replaced forested areas (Jordan et al., 1997). Almost invariably practices designed to increase the biological productivity of agricultural soils increase the biological productivity of waters draining these soils and may accelerate eutrophication. This causes problems with water use for fisheries, recreation, industry, or drinking water supply due to the increased growth of algae and aquatic weeds, and oxygen shortages caused by their decomposition (Sharpley et al.,1995). Eutrophic condition is defined as the state of a water body when it has an excess of plant nutrients from agricultural fertilizers, farming and human activities. Thus the water body that originally supported a great variety of flora and fauna can become depleted of oxygen supply due to excessive growth (Whittow, 1984). Although nitrogen, carbon, and phosphorus are associated with accelerated eutrophication, most attention has focused on phosphorus, because of the complication in controlling the exchanges of nitrogen and carbon between the atmosphere and a water body, and fixation of atmospheric nitrogen by blue-green algae (Sharpley et al., 1995; Thomann and Mueller, 1987). Nitrogen and phosphorus both affect eutrophication but in waters where salinity increases, nitrogen generally controls aquatic plant growth (Sharpley and Beegle, 2001).

One of the main sources of phosphorus and nitrogen found in nearby water environments of an agricultural watershed is runoff of the surrounding land. The disturbed soils found in agriculture lead to increased opportunity for runoff. Erosion is a function of rainfall amounts and intensities and soil texture, topography and management. Erosion in Prince Edward Island has been an ongoing problem (Day, 2000). Phosphorus is transported in dissolved and particulate forms. Particulate phosphorus includes phosphorus sorbed by soil particles and organic matter eroded during flow events and constitutes the major proportion of phosphorus transported from cultivated land (Sharpley, et al., 1992). Particulate phosphorus can provide a long term source of phosphorus for aquatic biota (Carignan and Kalff, 1980). This form of phosphorus is available for the long term because it is slowly released from the soil particles to which it is attached and becomes available to the aquatic plants. The Basin Head study examined levels of both soluble reactive phosphorus and total phosphorus.

In agricultural areas, biological processes are the main source of nitrate within the soil, and increases in stream nitrate concentrations over the last 30 years have been associated with changes in agricultural practice in terms of both increased use of fertilizer and changes in cropping practice (Domburg et al., 1998).

Some authors suggest that watersheds dominated by agricultural activity discharge greater amounts of nitrogen and phosphorus (Correll *et al.*, 1992), but other studies have shown that there is no correlation between the amount of agricultural land and nitrogen and phosphorus discharges by streams (Thomas *et al.*, 1992). Not all agricultural areas have high stream exports of nutrients (Thomas *et al.*, 1992). Therefore, agricultural effects on levels of nitrogen and phosphorus discharged to streams should be based on individual watershed circumstances.

2.8 Freshwater Stream Chemistry

One way in which nutrients travel from farmland to marine ecosystems is through overland flow and the nearby streams. Nutrients such as phosphorus can dissolve into runoff water or attach to soil particles that are carried into streams. Lory (1999) noted that there is little potential for phosphorus to leach through soil into groundwater, but the capacity of soil to absorb phosphorus can be overwhelmed on sandy soils or when the water table is close to the surface. Canadian Guideline levels for nitrate and phosphate in the freshwater stream environment are as follows:

Nitrate - No Canadian Guideline Level Exists

Nitrite - 60 μg/l

Total Phosphorus - No Canadian Guideline Level Exists (Alberta has adopted a limit of 150 μg/l)
(CCREM, 1987)

In previous studies it was noted that surface waters contain at least trace amounts of nitrates, but rarely more than 5000 μg/l and often less than 1000 μg/l (McNeely *et al.*, 1979; OME, 1981). Nitrite concentrations seldom exceed 1000 μg/l (McNeely *et al.*, 1979; OME, 1981). USEPA (1986) suggested total phosphorus concentrations in streams should not exceed 50 μg/l. Dunne and Leopold (1978) state that phosphate levels of 80 to 100 μg/l may trigger periodic algal blooms in fresh water, while long term eutrophication will normally be prevented if total phosphorus and phosphate levels are kept below 500 and 50 μg/l respectively.

2.9 Land Use Change Effects

Changes in land use from natural to agricultural soils almost inevitably lead to increased levels of nutrients being released from a field into surrounding waters. Improvement in agricultural production and subsequent increases in nutrient loads as a result of change in land use, application of fertilizers where none had been used before, and changes in the route and rate by which water is removed from the field cause increased nutrient losses (Skaggs et al., 1994). Most of the papers on land-use relationships to nutrient levels in surrounding waters have a timeline that lasted for at least a year and looked at different land uses at one particular period of time (Moreau et al., 1998, Osborne and Wiley, 1988). Moreau et al. (1998) looked at nitrogen and phosphorus draining from predominantly agricultural land, but there were also other influences such as urban activities and reservoirs that had significant effects on the results they obtained. They still found that non-point sources produced 95% of total nitrogen and 90% of total phosphorus for the whole river basin. Castro et al. (1999) examined land use changes that consisted of moving from conservational tillage using disk plough to no-tillage on residues without terracing. They examined these changes over an eight-year period of time for changes in runoff and erosion. It was found that the change to no-tillage resulted in a decrease in soil loss. Other studies used a modeling approach to assess effects of land use change and nutrient flows (Lørup *et al.*, 1998; Mander *et al.*, 2000).

Somers *et al.*, (1999) examined fresh surface waters and estuarine waters at areas around Prince Edward Island. The study examined both nitrate and phosphorus levels. It found that substantial increases in nitrate levels have occurred in the rivers over the past two decades. They also noted that there was an increase in estuarine phosphorus concentrations.

2.10 Management

Managing nutrient loss to surrounding waters is a very important process in today's society, whether it is to protect drinking water or to prevent eutrophication in lagoon environments. For the most part, separate management practices have been developed for the control of phosphorus and nitrogen because of the different chemistry and flow pathways of each nutrient (Sharpley *et al.*, 2000). Strategies trying to incorporate both will more than likely help to reduce one nutrient while compromising the effect of loss on the other. Therefore, since the focus of this study has been on phosphorus within the environment, the management practices that will be considered will focus on limiting phosphorus runoff.

The input of phosphorus from agricultural runoff can accelerate the eutrophication of phosphorus sensitive surface waters (Daniel, 1998). Non-point source pollution by phosphorus now accounts for a larger share of water quality problems than a decade ago (Sharpley *et al.*, 1994). However, profitable crop production depends on a strong management plan. Sensible fertilizer use can reduce erosion and runoff potential by increased vegetative cover. Phosphorus management is undoubtedly of agronomic and environmental importance (Sharpley *et al.*, 1994). The obvious management practices that control phosphorus dynamics and the potential for phosphorus loss from agricultural lands are decisions regarding application rate, application timing, and application method for phosphorus fertilizers, animal manures, municipal wastewater biosolids, or other phosphorus nutrient sources. Less obvious management decisions that affect soil phosphorus dynamics are crop rotation sequence, crop yield, crop residue management, tillage method and tillage timing (Coale, 2000).

In order to develop strategies that work in reducing non-point sources of phosphorus loss to water, a few things must be considered. There must be knowledge of the potential impact of agricultural phosphorus on aquatic biota, understanding the risk of loss under different methods of farming and management, and awareness of the large temporal and spatial variation in loss that occurs due to different hydrological conditions in different landscapes (Withers *et al.*, 2000). Therefore, the best management practices could be different for each individual watershed or even for each farm lot within a watershed.

Conservation tillage, fertilizer management, buffer strips or riparian zones, terracing, contour tillage, cover crops, constructed wetlands, and sediment basins may reduce phosphorus loss from surface runoff and erosion. Conservation Tillage is a planting system that leaves at least 30% of the soil surface covered after planting (Ongley, 1996). A common practice for farmers who use this type of conservation is not to till at all. Fertilizer management could include such things as split applications, soil testing, and fertilizing to achieve goals for reasonable yields (Skaggs *et al.*, 1994). Using fertilizer excessively will ultimately lead to increased runoff of nutrients therefore; fertilizers should only be applied at rates necessary to achieve reasonable crop yields. Buffer strips or riparian zones consist of the use of vegetated areas along the edge of fields (Department of Technology and Environment, 1999; Lory, 1999). These zones of vegetation help to slow runoff and trap coarse sediment. Terracing is a type of erosion control that is usually considered for steep slopes and on long gentle slopes. It is the use of soil embankments between flat surfaces to slow down runoff and erosion. These soil embankments are usually protected with vegetation or possibly even constructed from stone (Ongley, 1996). Contour tillage is the practice of planting crops along the land contours to avoid easy trenches for runoff (Ongley, 1996). Cover crop is when the field's usual crop is replaced with a complementary crop usually for a year. This different crop is chosen based on the ability to recharge the soil with the necessary nutrients. It also provides vegetative growth for the entire field, which in turn decreases runoff capabilities (Ongley, 1996). Constructed wetlands are a low cost and low technology and proven method to remove agricultural runoff of nutrients (Higgins *et al.*, 1993). This system involves construction of a wetland where one did not exist previously. The runoff water passes through the system and different macrophyte species are used to filter out the nutrients before it is released into the lagoon environment. The construction of sediment basins, also known as settlement ponds, involves digging out a basin to collect and store sediment during runoff events. While the water is detained in the basin, sediment is deposited out of the water column (Ongley, 1996). The best method for erosion control must be based on an individual study basis; no one method will be best for all agricultural areas.

2.11 Summary

It is apparent from the literature that lagoon environments are complex in nature and need to be studied on an individual basis. The Irish Moss located in Basin Head Lagoon is an important part of the lagoon and information regarding lagoon nutrients would be useful in maintaining the species. Sample collection of water for nutrient analysis and bathymetric information will help to obtain a clearer picture of what is happening within the lagoon. Phosphorus and nitrogen loading from streams are the main interest in agricultural areas as shown through the many studies found in the literature. Changes in the land use of these surrounding areas produces changes in nutrients being released to the nearby waters. The literature shows that management of the surrounding environment plays an important role in the levels of nutrients that reach receiving waters. The methods used throughout this study will be explained in the next chapter, detailing methodology from data collection through to analysis.

CHAPTER 3

3 Methodology

3.1 Introduction

This chapter takes a closer look at the Basin Head study area and surrounding environment and the methods used to study it. It will show the sampling locations for the study and describe methods of data collection. The rainfall data collection for the area during the study season will be examined. Methods for obtaining stream discharge levels and suspended solids are described. The physical lagoon environment and method used to produce the bathymetric map to assist in determining the hydrologic residence time of the lagoon are examined. Methods of collection for stream and lagoon water samples will be discussed. The methods involved in chemical sample analysis and suspended solid analysis are described. Ocean nutrient values are also an important component in the Basin Head Lagoon environment and their collection and use will be described. All of these collected data will then be used in the results and discussion chapter to analyze the situation within the Basin Head watershed during the summer of 2000.

3.2 Study Area

Basin Head Lagoon is located in eastern Kings County, twelve kilometres east of Souris, Prince Edward Island (Figure 3.1). The geology of the area consists of a thick, fractured formation of sandstone bedrock formed some 220 to 300 million years ago and covered by overburden (Environment Canada, 1996). The bedding of the area shows a shallow northerly slope of approximately two degrees. The region around Souris is generally low-lying with an extensive cover of glacial till material usually 1-3 m thick (van de Poll, 1983). The agricultural soils are developed from material derived mainly from reddish sandstone, soft red shale, and pebbly conglomerates.

The Basin Head Lagoon itself is characterized by a basin with a connection to the sea and a long narrow arm extending from the basin. The basin is about 760m long and 380m wide with a channel, 500m long, connecting it to the Northumberland Strait. The channel is approximately 2.5m deep and was formed when the former channel at the eastern end of the system infilled. The basin itself is approximately 1-1.5m deep at high tide and 0.5-1m deep at low tide. A long narrow arm extends three km east of the basin that is approximately 100-130m wide. The arm separates a large sand dune system to the south, referred to as the singing sands, from agricultural land to the north (Figure 3.1). The agricultural fields support a variety of crops including potatoes, clover, and oats.

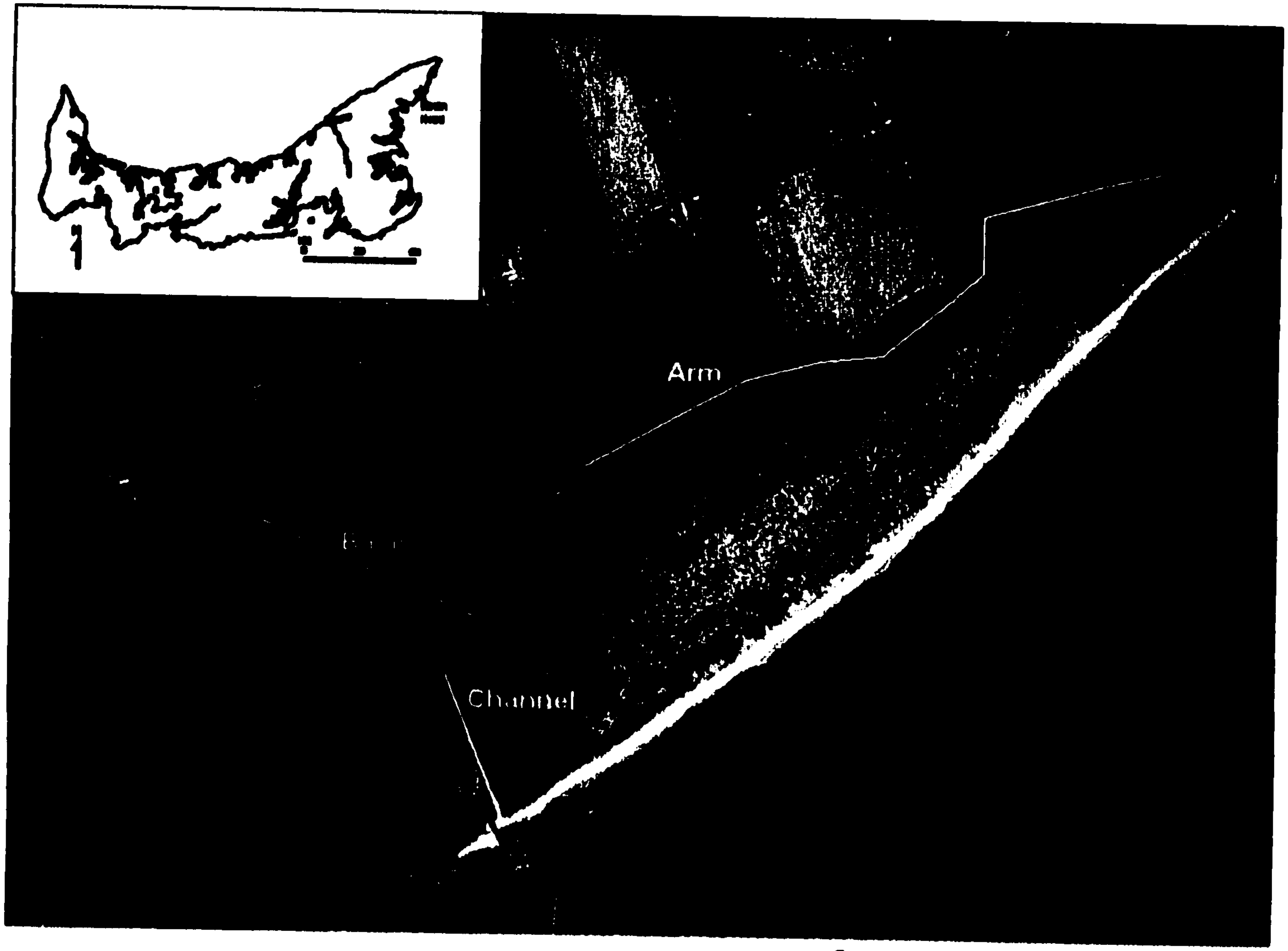
The Basin Head watershed consists mainly of agricultural fields containing potato crops. There is some forest growth, residential areas and a potato processing factory. A land use map obtained from the P.E.I. Department of Fisheries, Aquaculture and Environment, Fish and Wildlife Division (2000) shows the topological features of the Basin Head watershed (Figure 3.2). The area to the north of the Basin Head Lagoon is characterized by approximately 65% agricultural land, 30% forested land, and 5% residential. To the south of the lagoon 90% of the land is vegetated sand dune and 5% is a salt marsh. Figure 3.3 shows an aerial oblique of the Basin Head area. The area is dominated by sand and sandstone bedrock, this allows for increased transportation of nutrients through groundwater flow to the stream and lagoon environment. The study completed in 2000 examined only the stream flow component of the watershed but one should consider the importance of groundwater flow in Basin Head.

3.3 Data Collection

Sampling locations were set up within the lagoon and on the three streams entering the lagoon for data collection (Figure 3.4). Stream 1 has a length of approximately 1.0km while streams 2 and 3 have lengths of 1.8 and 1.9km respectively. Locations within the lagoon were located as close as possible to locations established in 1979 during the study conducted by McCurdy (1979). The previous study did not report exact locations of sampling, so the stations were set according to a map obtained from the previous study (refer to Figure3.5). Coordinates from a Garmin hand held GPS 48 system were taken at each of the six stations (see Table 3.1).

Location 1	46°23.87' N	62°04.84' W
Location 2	46°23.47' N	62°05.59' W
Location 3	46°23.24' N	62°06.36' W
Location 4	46°23.14' N	62°06.60' W
Location 5	46°23.00' N	62°06.76' W
Location 6	46°23.12' N	62°07.14' W

Table 3.1 GPS Locations of Lagoon Sampling Stations



Government of Prince Edward Island, 2000

Figure 3.1 Air Photo and Location Map of Basin Head, Prince Edward Island

Figure 3.2 Proposed Marine Conservation Area at Basin Head

Figure 3.3 Aerial Oblique of Basin Head, P.E.I.

Government of Prince Edward Island, 2000

Figure 3.4 Basin Head Lagoon and Stream Sampling Locations

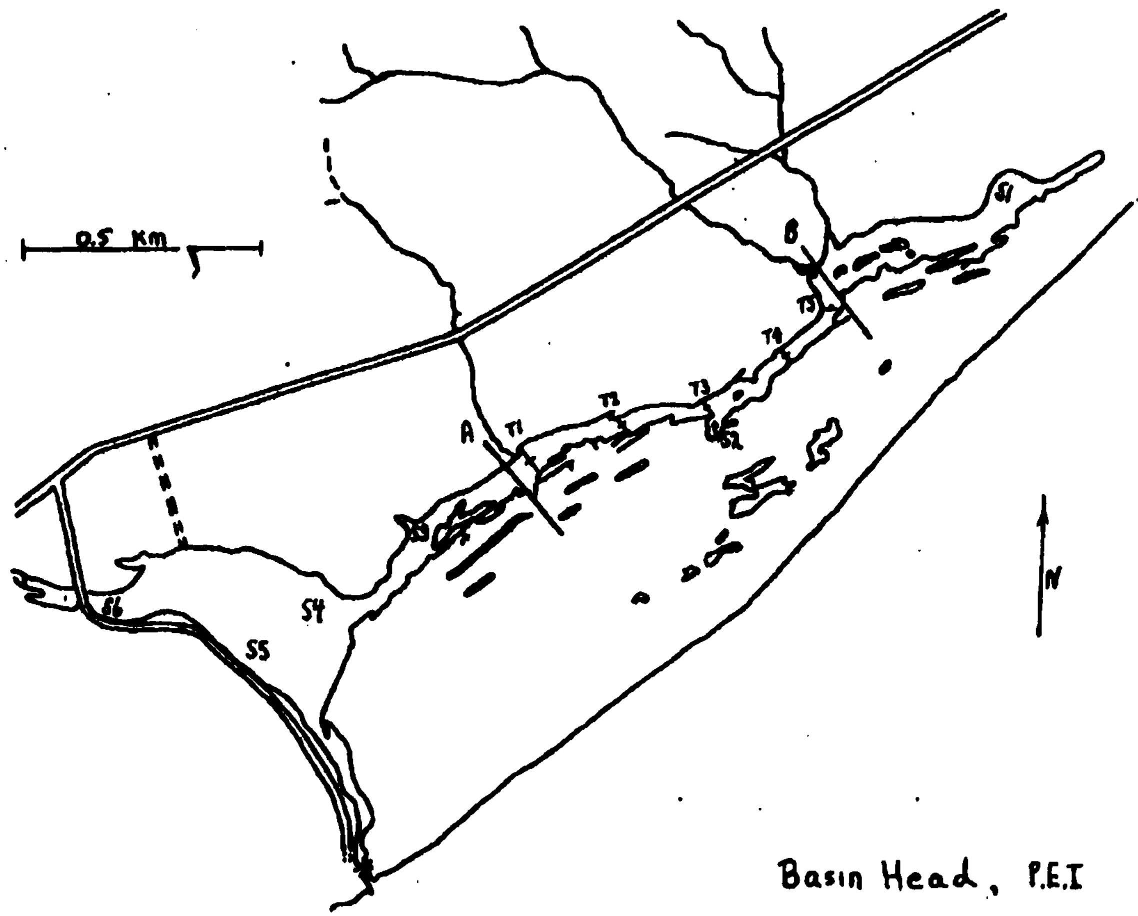
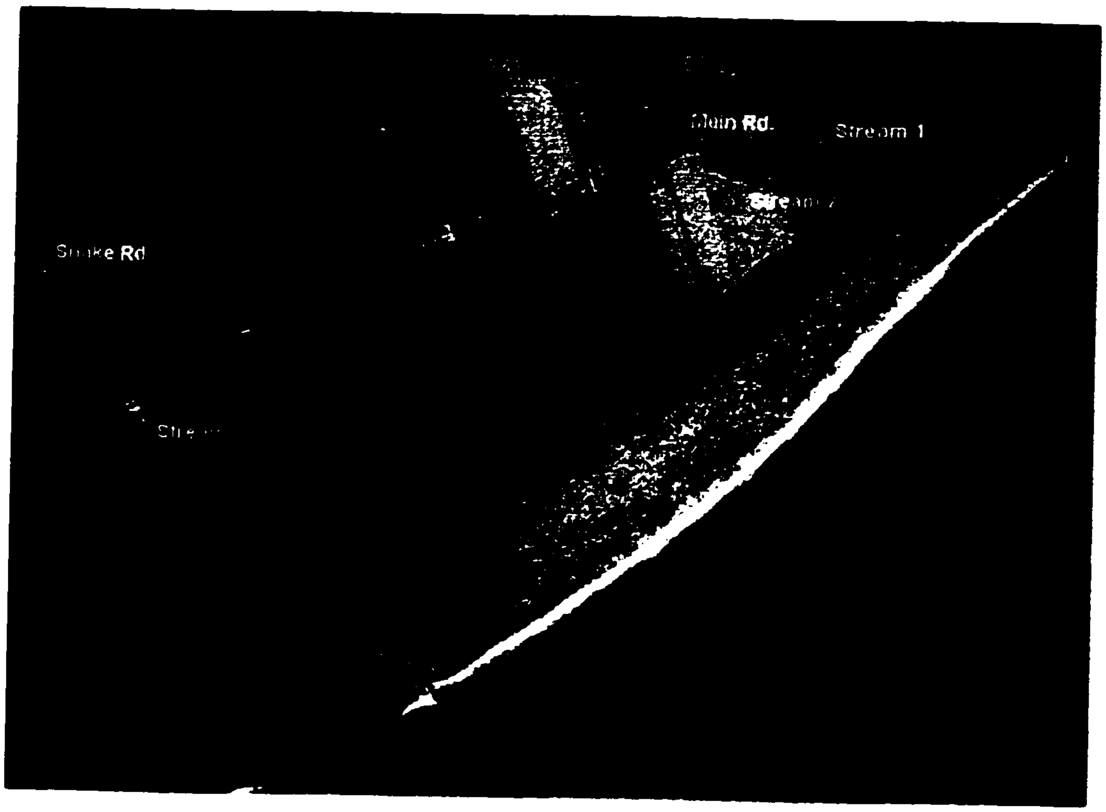


Figure 3.5 Basin Head Lagoon Sampling Locations

McCurdy, 1979

3.3.1 Rainfall

Rainfall measurements were collected over the watershed area surrounding the Basin Head Lagoon in 5 places (see Figure 3.6).



Government of Prince Edward Island, 2000

Figure 3.6 Rain Sampling Locations

Rainfall was manually measured throughout the study period, using rain gauges. The locations were chosen based on their accessibility and ability to provide information about the entire study area.

Precipitation measurements were taken within the basin on days of adequate rainfall that warranted sample collection. Measurement of rainfall amount was taken shortly after rainfall ceased. Other days that had slight amounts of rainfall were considered trace amounts and therefore given values of zero. Rain gauges were not set up throughout the basin until mid to late June therefore no rain measurements for the Basin were collected in the month of June.

Rain was collected using identical juice containers attached to stakes placed in the ground (Figure 3.7).

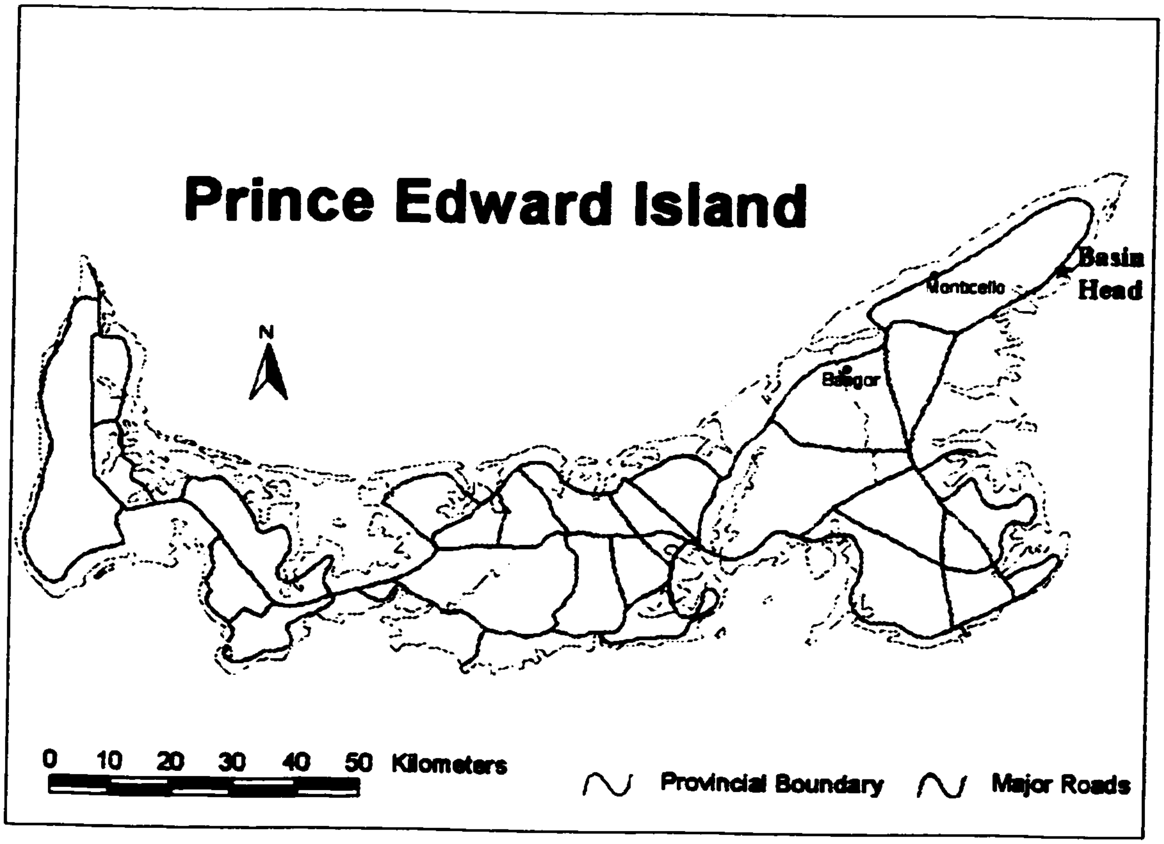
Figure 3.7 Rain Gauge

The stakes were used to ensure that the containers remained upright during the entire study period. The container dimensions were as follows:

Height = 17.5 cm
Diameter = 10.5 cm

The rainfall was collected and measured using a graduated cylinder to give an amount in ml of rainfall. These data were converted to mm by obtaining the area of the container opening (πr^2).

Precipitation data from monitoring stations operated by Environment Canada's Climate Centre were also obtained for the summer of 2000. There were no stations in operation near the Basin Head area at this time. Therefore, the closest data locations that could be obtained were in Bangor and Monticello. Proximity of these towns to Basin Head can be seen below (Figure 3.8). This information gave daily precipitation values for the entire study period.



Geomatics Canada, 2001

Figure 3.8 Locations of Monitoring Stations

The rainfall information collected from Environment Canada were used to identify if there was any apparent relationship between rainfall at these locations and stream discharge at Basin Head. It should be noted that precipitation collection at the Environment Canada sites used an AES Rain Gauge Type B System. This system is a plastic collecting funnel and outer container. The collecting funnel is 36cm high, has an opening 100cm^2, and is mounted 40cm above the ground. The gauge used in this study was 17.5cm high, had an opening of 86.59cm^2, and was mounted on the ground in a clear and open area away from any obstructions. This may represent some error between the two sets of data. This error is considered minimal, as the measurements between the two rain gauges are similar. Regression analysis was performed to determine if the rainfall data would be useful in representing daily rainfall amounts at Basin Head.

3.3.2 Discharge and Sediment

The nutrient inputs into the lagoon were monitored through sampling of the three main streams entering the lagoon. Wiers were built along each of the three streams (see Figures 3.9).

Figure 3.9 Weir Built on Stream 2

Weirs for Basin Head were constructed out of plywood that were placed into the streams and run into the banks approximately one foot. A 90° angle was cut into the middle of the plywood prior to placing it in the stream in order to let the stream water flow through.

Plywood was a suitable construction material at Basin Head as the streams were small and narrow. Repairs to the weirs were necessary during the first week after construction due to erosion but they remained sound for the rest of the field season. The weir on stream 1 had to be removed and placed further up stream within the first week after it was concluded tidal influence would be a problem in the current location. The weirs on each of the three streams remained in place throughout the field season and made it easy to gain knowledge of discharge levels through depth measurements using a meter stick. The depth was taken approximately two to three feet behind the weir on a weekly basis.

Discharge was calculated for each river from the depth measurements collected at the weirs. The following calculation;

$$Q = 1.343H^{5/2}$$

was used to determine discharge where Q = discharge, m^3/sec and H = head of the water above the apex of the V-notch, m (Sanders, 1998). This information was graphed for each river to show how much fresh water was flowing into the lagoon during each sample period. Since stream 3 was larger than the other two streams that were monitored, it was necessary to also show the minimum, maximum and average discharge from all three streams. This clearly showed that stream 3 had the most potential to impact on the lagoon system. A graph was produced to examine the relationship between rainfall at Basin Head and discharge of the three streams. Total freshwater discharge into the lagoon during sampling was examined along with an estimate of the average total discharge over the entire study period. A 24-hour analysis of discharge and sediment load was also conducted on stream three which gives a continuous look at what is happening on any given day.

Suspended solid analysis was conducted on each of the three stream inputs. This was conducted by taking a grab sample at the centre of the stream using polyethylene containers approximately 250ml in size. The samples were then cooled and later frozen until analysis was conducted.

Sediment was collected within the streams to examine suspended sediment amounts at time of sampling. Quality assurance was considered as two to three samples were collected at one time during sampling of the three streams. Some sampling using plastic baggies was necessary. Unfortunately, this was later determined to be an inadequate method for sampling as loss of samples occurred during transportation for analysis.

3.3.3 Bathymetry

The basic bathymetry of the lagoon was also obtained throughout the field season. The first stage was to set a reference location in order to allow for depth correction of tidal effects. A stake measuring two meters in height was placed within the lagoon and attached to the nearby dock (Figure 3.10). The zero measurement of the reference depth was at ground level on the stake. The stake was located approximately two to three feet in from the high water mark. Therefore the zero reference for the bathymetry completed during the study is arbitrary. In most cases, geodetic zero is used as a standard reference point. In this case, the reference point was unknown so an arbitrary one was assigned where stake placement was possible and allowed monitoring during sampling. The depth was noted on an hourly basis during the bathymetric sampling. Depth soundings were obtained by connecting a straight line of fishing rope from one side of the basin to the other. Effort was made to keep the rope out of the water and pulled tightly to make a straight line but this could not always be satisfied due to the distance across some transects. Therefore some error could be introduced through this method of data collection

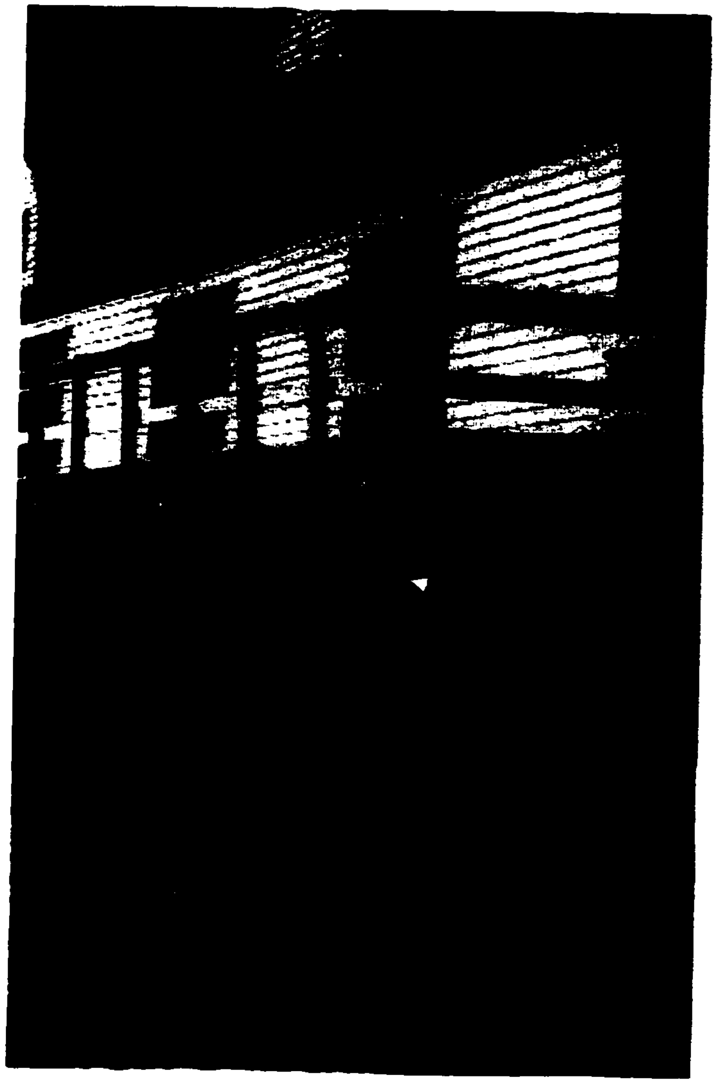


Figure 3.10 Tidal Measurement Stake

The line was marked at 10m intervals and depths were taken and noted, along with time, with a measuring stick using the high tide mark as the reference point (Figure 3.11). Each line was approximately 20m apart and covered the entire lagoon. This process was based on procedures described by Wright (1974).

Figure 3.11 Bathymetry Measurements

The bathymetric map for the Basin Head Lagoon was constructed using ESRI software. The only suitable base map for the area was obtained in Adobe Illustrator format. The first step was to import the file into PCI and georeference the map to a hard copy map of the area. Then the outline of the basin was traced using drawing tools and saved as a vector layer. There were problems with directly importing this vector layer into ArcView. Therefore, the vector layer was exported to MapInfo where the file was imported and then directly exported in .mif format. This allowed ArcView to accept the file and the "mif to shape" tool was used to bring the file into ArcView as a shape file. A line layer was added to contain all of the transect lines throughout the lagoon and a point layer was added with all of the depth measurements. A .tiff file of an airphoto taken during the summer of 2000 was georeferenced in ArcGIS 8.1 and imported into the ArcView file to be used as a background display.

Before the depth measurements could be entered into the point layer they had to be transformed to remove the tidal effect on depth. The data collected at the stationary monitoring station were graphed for each day. The tidal graph was then used to find the tidal level at specific times that depth measurements were taken. The tidal level was then subtracted from depth measurements taken at the same time throughout the lagoon. Only one tide gauge was set up in the basin, as tidal lag was minimal for the entire lagoon. Tide levels within the lagoon and on the ocean side remained equal throughout both high and low tide. In this type of environment, minimal tidal lag may be explained by water flowing through the dune system into the lagoon. Corrected depth measurements were then entered into the point layer of the ArcView file.

ArcView 3D Analyst was used to create the bathymetry for Basin Head Lagoon from the entered depth measurements. A grid was produced within ArcView of the Basin Head Lagoon. The resulting grid extended past the boundaries of the lagoon because of the placement of depth measurements and the way the program calculates the grid. The region containing the lagoon had to be clipped from the grid. A script created by Tom Van Niel (Nov. 3, 1999) was downloaded from the ESRI web site (www.esri.com, May 2001). The purpose of the script was to clip the input grid by the clip theme. The grid was clipped using the lagoon outline shape file as the clip theme. ArcGIS 8.1 was used to convert the clipped grid to a Triangulated Irregular Network (TIN). The TIN was used to find surface depths for the entire lagoon area.

The TIN that was created allowed the calculation of lagoon volume, which was very important for the calculation of hydrologic residence time of the lagoon. The lagoon volume was calculated in ArcView using the area and volume function giving a volume in m^3. The hydrologic residence time of the lagoon was calculated using a flushing time equation based on differences in salinity.

The following equations were used to attain residence time:

$$R + V_{in} = V_{out}$$

$$V_{out} = R / \left\{ 1 - \frac{S_{in}}{S_{out}} \right\}$$

And,

$$V_{in} = V_{out} \frac{S_{in}}{S_{out}}$$

Where, R = Stream Discharge Rate, V_{in} = Inflow Amount, V_{out} = Outflow Amount, S_{out} = Ocean Salinity Levels, and S_{in} = Lagoon Salinity Levels. Solving for V_{out} and V_{in} gives amounts in m^3/sec for the amounts flowing in and out of the system. To attain a time value for residence the following equation was used:

$$\text{Time (Days)} = \frac{\text{Volume}}{V_{in}}$$

(B.Petrie, personal communication, March 15, 2002)

This is also known as the freshwater fraction method (Kelly, 1998). The residence time calculation will be useful in determining the stream nutrient impacts on the lagoon. If the residence time is found to be short it is assumed that the lagoon concentrations should be close to values of ocean nutrient concentrations.

3.3.4 Chemistry

The main focus of the research was water quality and nutrient impact; therefore most of the fieldwork consisted of gathering water samples. A fifteen-foot aluminium boat equipped with an outboard motor was used to navigate the lagoon. The lagoon was very shallow in many areas of the arm during low tide so a canoe was used to gather data at these times. Water samples were collected at six stations throughout the lagoon on a weekly basis (refer to Figure 3.4). The stations were established on June 17, 2000. The locations were marked for easy identification through the use of concrete blocks with rope and buoys attached. The water sample collection within the lagoon began on June 17, 2000. The sample bottles used were 30 ml Polyethylene containers that had been previously cleaned and prepared for sampling in the lab. The bottles were rinsed three times with lagoon water in the sample location and labelled for later identification. The sample was collected at mid-depth using a 60 ml syringe that had also been previously rinsed with lagoon water. The collected sample was immediately filtered through a Watman 0.45 μm membrane filter into the sample bottle and placed in a cooler (see Figure 3.12).

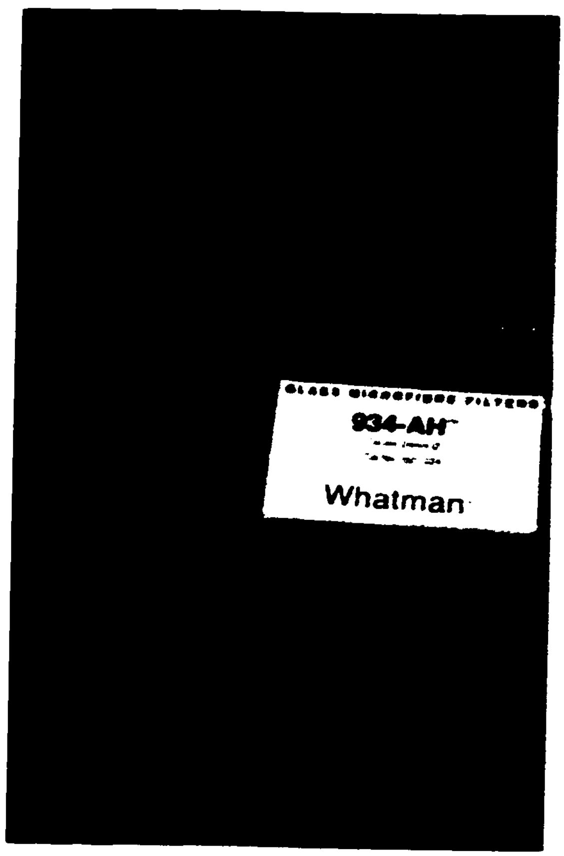


Figure 3.12 Sampling Syringe and Whatman Filters

Depth was measured at each location using a measuring rod. Air and water temperature were noted using a hand held thermometer. The salinity level was recorded through the use of a portable salinity refractometer, Model # RST-101 (Figure 3.13). The same measurements were taken at all sample locations throughout the lagoon.

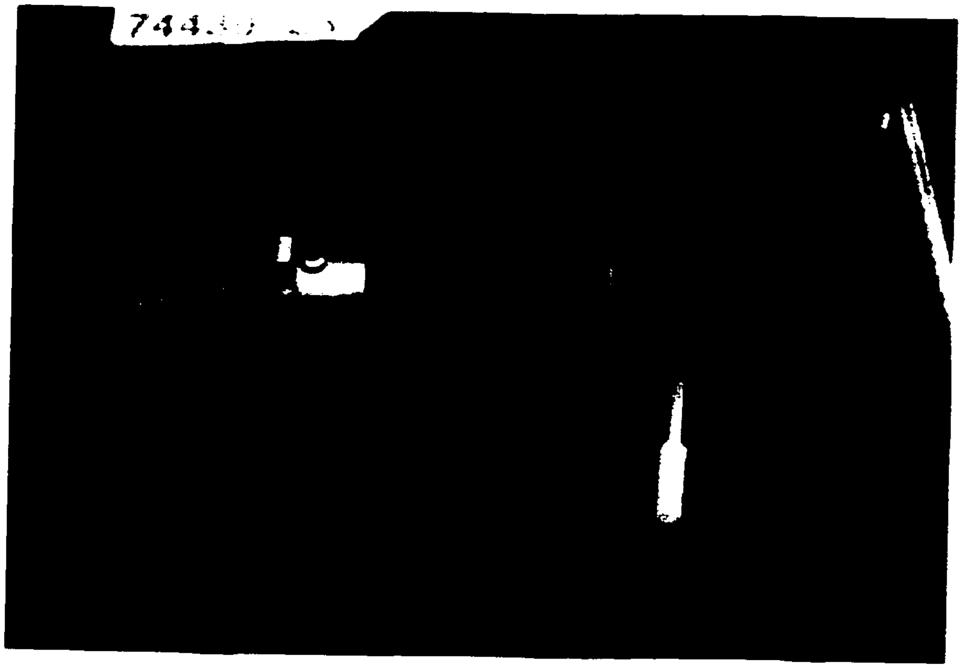


Figure 3.13 Salinometer and Thermometer

The syringe was rinsed with distilled water between each sampling location. After all sampling was completed samples were placed in a freezer until lab analysis was completed.

In order to maintain quality control three samples for soluble nutrient analysis were collected at each site. Two samples were split from one grab and the third was collected at a slightly later time. The samples collected throughout the lagoon were used to analyze levels of Nitrate (NO_3^-), Nitrite (NO_2^-), and Soluble Reactive Phosphorus (SRP). Table 3.2 below outlines sample collection at each Basin Head site.

	Streams	Lagoon
Phosphate	✓	✓
Nitrate	✓	✓
Nitrite	✓	✓
Total Phosphorus	✓	
Suspended Solids	✓	
Salinity		✓
Air Temperature	✓	✓
Water Temperature	✓	✓

Table 3.2 Summary of Sample Collection on Stream and Lagoon at Basin Head

Nutrient levels within the streams were monitored through water sampling. The soluble nutrients were collected in the same manner as within the lagoon. The bottles were pre-rinsed within the stream, as was the syringe; a different syringe was used for salt and fresh water sampling. The sample was collected with the syringe at mid-depth and in the centre of flow of the stream. The syringe was facing upstream and approximately two to three feet upstream from the weir. The sample was immediately filtered through the Watman 0.45 μm membrane filter into the sample bottle and placed in a cooler. Three samples were collected on the streams to maintain quality control, two samples were split from one grab and one was collected a few minutes later.

Total Phosphorus (TP) was also monitored on the three input streams. These were collected in 50ml polyethylene containers that had been cleaned and prepared for collection by the lab that completed the analysis. The containers were rinsed in the sample water three times and then collection was completed by placing the container in the middle of the stream at mid-depth and turning the bottle upstream to collect the water sample. The samples were then placed in a cooler and frozen as soon as possible after collection until analysis was possible.

3.4 Sample Analysis

The soluble nutrient samples were sent to the Bedford Institute of Oceanography located in Dartmouth, Nova Scotia. They were thawed prior to analysis for phosphate, nitrate, and nitrite. The method for phosphate analysis was based on Murphy and Riley (1962). A modification of the method was used for auto-analyzers (Technicon Industrial Method 155-71W, 1973). Determination of phosphate depends on the formation of a phosphomolybdenum blue complex. A single reagent solution is used consisting of an acidified solution of ammonium molybdate containing ascorbic acid and a small amount of antimony. The detection limit for phosphate was 0.02μM.

Nitrate analysis is based on the measurement of a diazo dye formed by the reaction between sulfanilamide and nitrite, which has been produced by the reduction of nitrate to nitrite on a copperized cadmium column (Technicon Industrial Method 158-71W, 1972). The analysis of nitrite is the same as that for nitrate except without the cadmium column reduction step (Technicon Industrial Method 161-71W, 1973). The detection limit for nitrate was 0.03 μM. Due to money constraints, only 2 of the 3 samples taken at each site were analyzed.

The values were represented as μM therefore each had to be converted to μg/l before comparison could be completed with all nutrients. The conversion was completed by multiplying by molecular weight of each compound in relation to phosphorus, and nitrogen. For example, phosphate values were multiplied by 31, which gave the result μg/l phosphate – phosphorus.

The analysis of total phosphorus was completed at the Prince Edward Island Department of the Environment Lab located in Charlottetown, Prince Edward Island. The levels were established using the autoclave digestion method based on Koroleff (1983). The samples are digested in an autoclave for 30 minutes at 121°C with potassium persulfate and sulfuric acid + nitric acid to convert all phosphorus to orthophosphate. The orthophosphate is then analyzed using the same procedure as described above. The detection limit for total phosphorus was <5μg/l. The lab also conducted quality control procedures throughout the analysis to ensure reliability of the results.

Water samples were sent to Wilfrid Laurier University for analysis of suspended solids. Analysis was completed using vacuum filtration of the samples through 0.45μg Watman glass microfiber filters. The samples were thawed and volume was obtained using a graduated cylinder. The filters were dried in an oven for 24 hours at 80°C then the weight of each filter was obtained using a digital scale. The dried filters were placed in plastic funnels over glass bottles. There was a line connecting all the funnels to a vacuum pump. The samples were poured into the funnels and the vacuum turned on which helped to bring the water down through the filter leaving the suspended solids behind. The filters were then placed in the oven for 24 hours of drying. After the filters were dry, they were weighed with filter and sediment. The concentration of suspended sediments was calculated from the following equation:

$$[ss] = \frac{\text{(mass of the filter plus sediment, grams) - (mass of the filter, grams)}}{\text{volume (litres)}}$$

Giving a suspended sediment concentration in grams/litre as described by McCave (1979).

3.5 Ocean Nutrients

The ocean affects nutrient concentrations found in nearby waters along the shore. The amount of effect would be different for each individual situation. The residence time of the Basin Head Lagoon was calculated in order to determine the effect of ocean nutrients on this area. If the lagoon had a short residence time, it was assumed that the nutrient concentrations within the lagoon would closely resemble the ocean nutrient levels. This would not be the case if residence time were long (Kelly, 1998). Ocean nutrient levels for June, July and August of 2000 were collected at a fixed station located off Shediac, New Brunswick that is situated in the Northumberland Strait by Fisheries and Oceans Canada. This was the closest data collection point to the Basin Head Lagoon. Shediac is approximately 200km away from Basin Head. Data were obtained from Brickman and Petrie (In Prep) that identifies the relationship between nutrient levels found in the Shediac, N.B. area and the Basin Head area in years other than 2000. Figure 3.14 and 3.15 below shows the nutrient concentrations of nitrate and phosphate for the two areas.

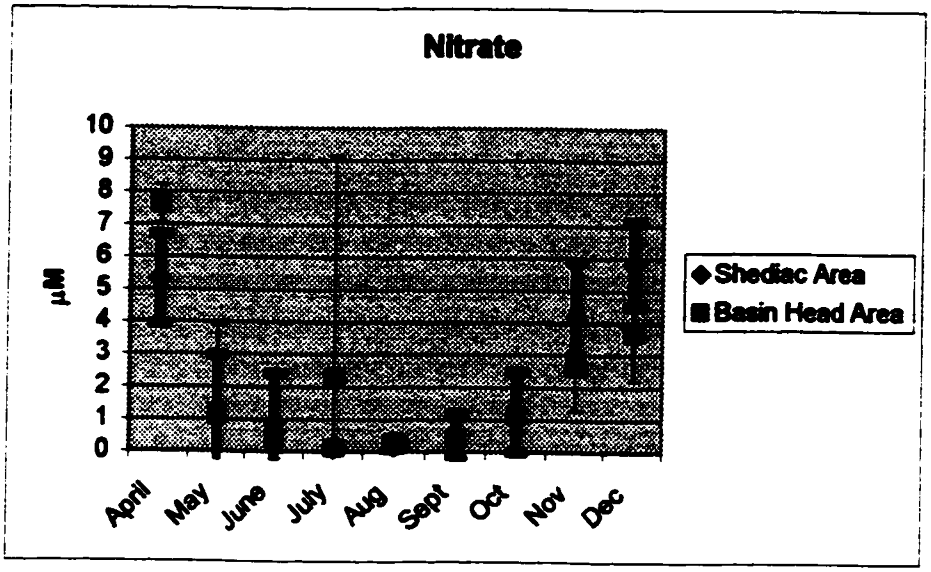


Figure 3.14 Nitrate Comparisons Between Shediac, N.B. and Basin Head, P.E.I.

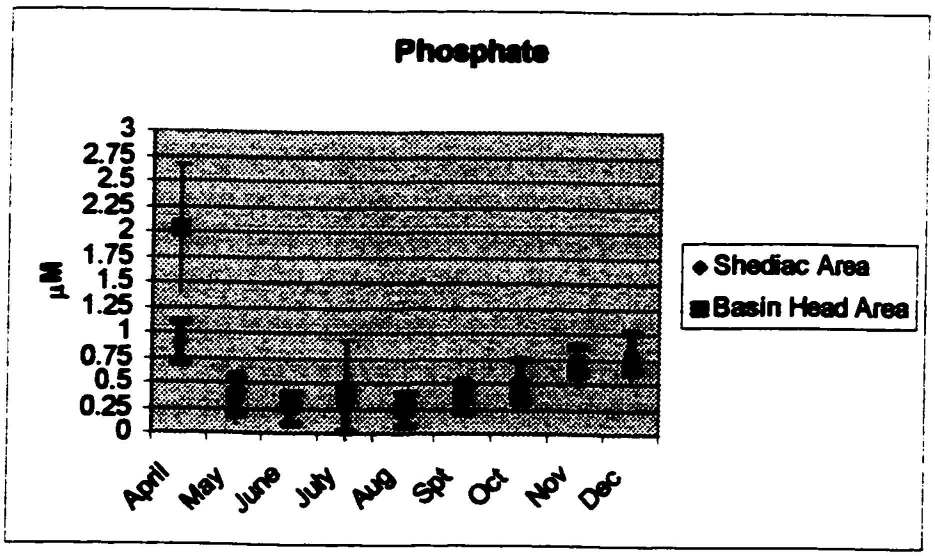


Figure 3.15 Phosphate Comparisons Between Shediac, N.B. and Basin Head, P.E.I.

It is evident from these graphs that concentration levels collected in Shediac can be used with confidence to represent ocean nutrient concentrations in the Basin Head area. The ocean nutrient levels for the summer of 2000 were placed on a graph with the lagoon concentration levels collected throughout the study to determine if any relationship existed.

3.6 Summary

This chapter examined the ways in which the study of the Basin Head Lagoon and watershed were completed. It examined the study area, data collection methods for rainfall, discharge and suspended solids of the streams, bathymetry, and chemistry samples. Sample analysis from all of the collected samples was detailed. The inclusion of ocean nutrient data and collection of this information was discussed. The following results and discussion chapter will show the actual data and analysis obtained throughout the study and provides some discussion about what the data implies.

CHAPTER 4

4 Results and Discussion

4.1 Introduction

The information gathered at Basin Head Lagoon during the summer of 2000, along with information obtained from outside sources, such as a contour map, ocean nutrient concentrations, and climate data, were used to assess the conditions in and around Basin Head. The purpose of this chapter is to examine the cause and effect relationship between rainfall, stream flow, and the lagoon. Only the stream flow transport component of the system to the lagoon was considered throughout the Basin Head area.

This chapter will present the following information on the Basin Head study. Weather information around Basin Head during the summer of 2000 and comparison to climatic normals will be examined. Comparison of weather at Basin Head to areas nearby where weather-monitoring stations are run by Environment Canada. The hydrology of Basin Head in terms of stream inputs into the lagoon will be examined. This includes examining the relationship between stream discharge and rainfall and total freshwater inputs to the lagoon.

Sediment is an important means of nutrient transport and was also examined during the field season. Suspended solid data for all three streams are shown along with an examination of relationships between suspended solids and stream discharge. Sediment load was also calculated to show how much sediment is entering the lagoon for a specific period of time. The physical properties of the lagoon are a very important part of any study examining stream impacts on the lagoon. The Basin Head environment is a very complex system due to the inputs from the ocean through the tidal cycle. The impacts of the tide on the lagoon volume and chemistry were examined through the completion of the bathymetric model of the lagoon. The bathymetry model allowed for calculation of residence time for the lagoon.

The next topic of the results chapter is the examination of nutrients. Chemistry analysis throughout the summer in both the stream and the lagoon examined nitrate, nitrite, and phosphate. Total phosphorus was collected only on the streams. Nutrient concentrations were graphed against discharge to determine if any relationship existed. Mass flux of nutrients was also calculated and graphed to show amounts entering the lagoon. The data that were obtained throughout most of the study are measured at instantaneous levels within each stream. On August 21 & 22 a 24-hour sampling of stream three was conducted to examine continuous levels of discharge, suspended solids, and nutrients. This chapter will present these data, show graphs of mass flux of nutrients, and examine 24-hour inputs of nutrients, water, and sediment into the lagoon. Discharge levels will also be compared with sediment levels to determine if any relationship exists.

The next step is to examine the nutrient concentrations that exist within the lagoon. These concentrations are compared to nutrient concentration levels obtained from the ocean to establish connections between the two concentration levels. Lagoon chemistry is then compared to chemical inputs from the streams to determine the effect, if any, the streams have on the lagoon. In order to examine how nutrient concentration levels have changed over time comparisons are completed between the 2000 data and data collected in 1979. The compilation of all of the data will allow for discussion of the conditions within Basin Head and documentation of potential harmful effects this may have on the lagoon.

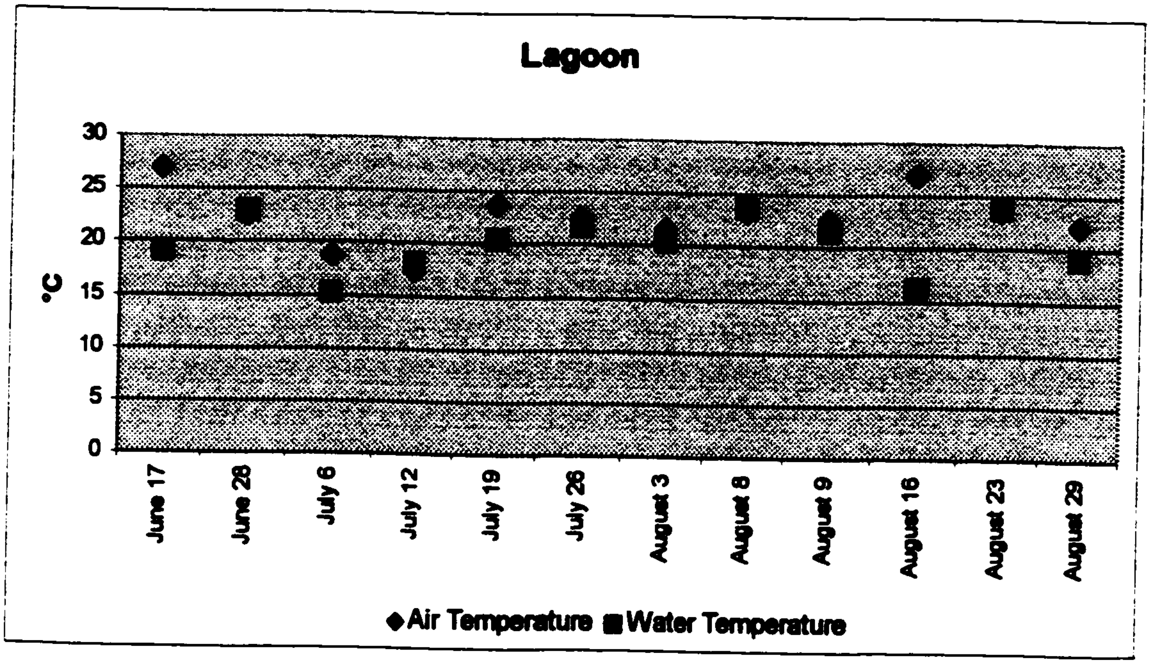
4.2 Weather and Climate

Prince Edward Island is located on the eastern coast of Canada in the Gulf of St. Lawrence. The Island's location is 46 degrees N latitude, -63 degrees W longitude. This places it in a humid continental climate zone which features mild to warm summers and cold winters. The average rainfall in Prince Edward Island for June, July, and August is 87.5mm, 78.5mm, and 90.1mm respectively. The average minimum and maximum temperatures for June, July, and August are 10.1°C & 19.4°C, 14.4°C & 23.1°C, and 14.1°C & 22.7°C respectively (Government of Prince Edward Island, 2002).

Data obtained from Environment Canada show that compared to long-term climate data, temperature during the summer of 2000 was near normal while precipitation was below normal for Prince Edward Island (Environment Canada, 2000). Figure 4.1 shows the average air and water temperatures found for the streams and lagoon during the field season. Historical averages for air and water temperatures were not available for the Basin Head area.

The below average level of precipitation was also confirmed from rain gauge data collection throughout the summer. Figure 4.2 shows rainfall amounts throughout the entire summer for locations at Bangor, Monticello, and an average of all five collections sites at Basin Head together (refer to Figures 3.8 and 3.6). A difference between Basin Head rain gauges and Environment Canada's gauges does represent possible instrument error but this is considered minimal. The x-axis is displayed as Julian days, day 167 is June 15th and day 243 is August 29th. Rainfall amounts for each month and each collection site at Basin Head throughout the summer can be seen in Appendix A. Rainfall sampling occurred on June 19th, 22nd, July 4th, 10th, 19th, August 9th, and 15th.

The two rain days in June have no value for amounts, as the rain gauges were not yet set up.



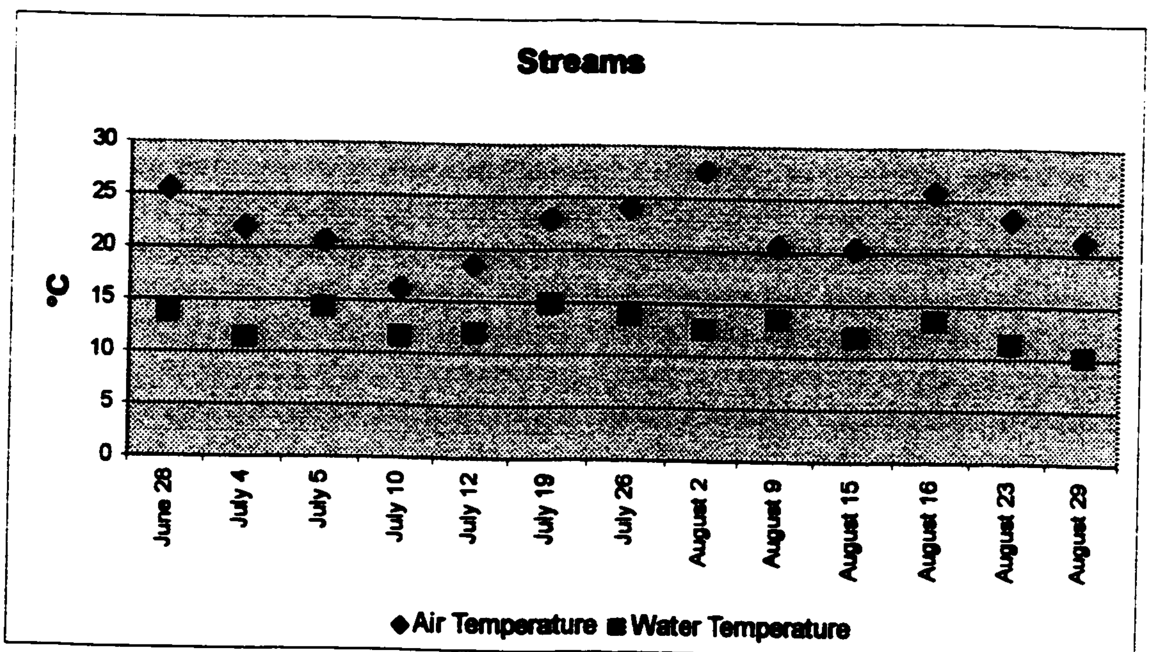


Figure 4.1 Air and Water Temperature For Streams and Lagoon During Sampling

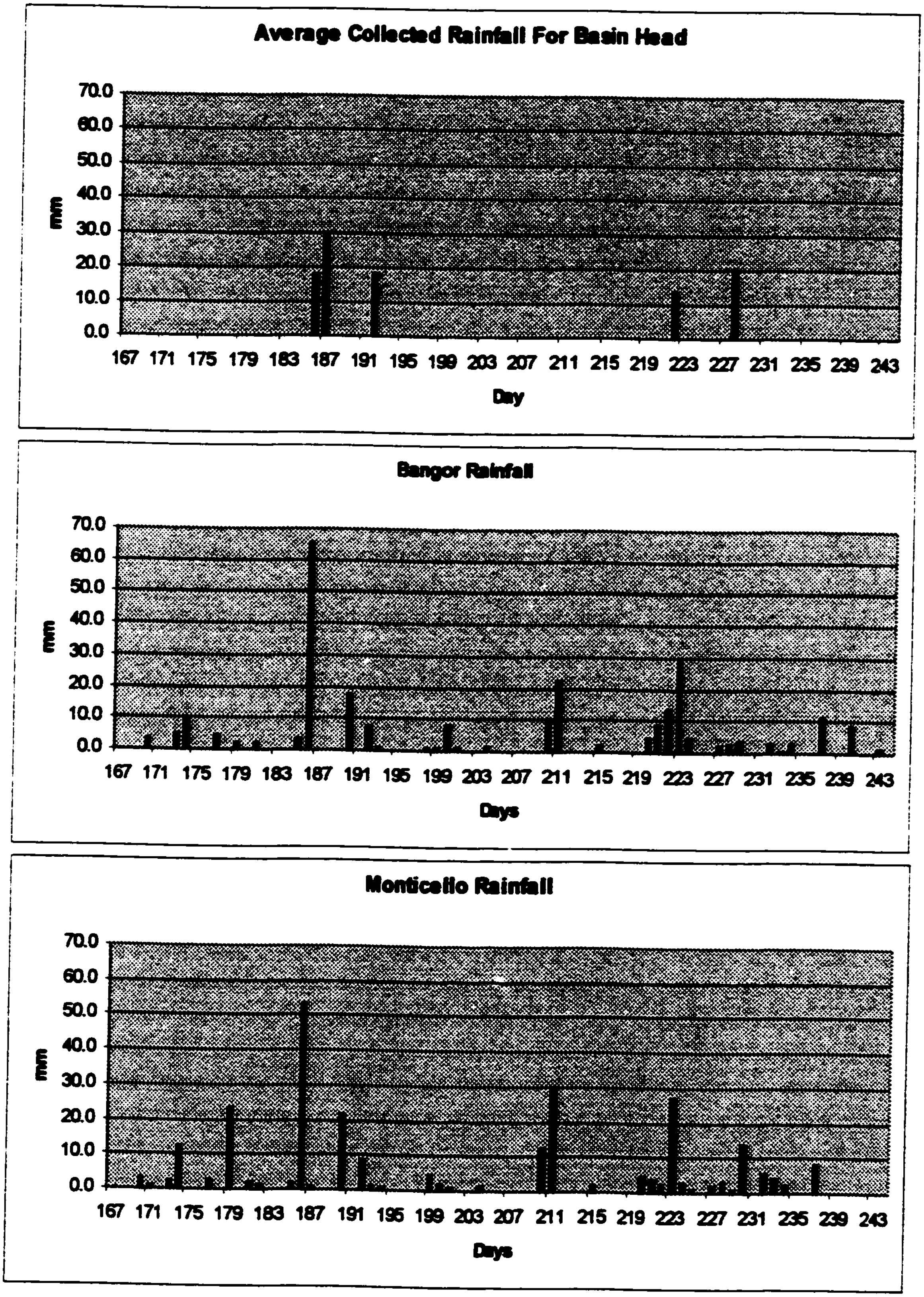


Figure 4.2 Rainfall Amounts For Entire Summer

Relationships between rainfall at Bangor and Monticello and discharge at Basin Head were explored through regression analysis. This was completed to see if the daily rainfall data from Bangor or Monticello could be substituted for the intermittent data obtained at Basin Head. The corresponding dates for discharge data and rainfall at each location were placed into an excel spreadsheet and regression analysis performed on each for the three streams at Basin Head. For Rainfall at Bangor the analysis produced low values for r^2 and the same was true for the data from Monticello. Stream 1 values were 0.24 and 0.21 for Bangor and Monticello respectively, Stream 2 was 0.25 and 0.12, and stream three was 0.41 and 0.35. A further analysis was completed leaving out days where high discharge values appeared not to be related to rainfall. These days were July 26th (208), August 2nd (215), and August 29th (242). On these days, discharge levels were high while precipitation levels were low or none at all. The regression analysis from this new set of data still yielded low r^2 values of 0.21, 0.50, and 0.64 for Bangor. The r^2 values of 0.50 and 0.64 may be significant but with the limited amount of data points this cannot be confirmed. Therefore it was concluded that there was not enough reason to believe these areas would be a suitable substitute for daily rainfall at Basin Head. One can assume from this analysis that this area shows evidence of being effected by localized rainfall events.

Watershed areas for each stream were calculated from a topographic map with a scale of 1:8000 containing contours at an interval of 2m. A 1cm grid was placed over each delineated watershed and area was calculated from the number of grids falling within the watershed. The watershed areas for each stream are as follows:

Stream 1 – 1.19 km^2
Stream 2 – 2.07 km^2
Stream 3 – 4.38 km^2

From these measurements, the amount of rainfall that fell during events over each watershed could be calculated. The results for each rainfall event can be viewed in the table below (Table 4.1).

	Stream 1	Stream 2	Stream 3
04-Jul	21303.4	37057.1	78410.8
05-Jul	34248.2	59574.6	126056.4
10-Jul	21658	37674	79716
09-Aug	16326.8	28400.4	60093.6
15-Aug	24038	41814	88476

Table 4.1 Rainfall Amounts for each Watershed in mm^3

This shows approximately how much rainfall occurred over each watershed but it is difficult to make direct assumptions about contribution amounts to stream flow from these data because soil drainage information is unknown. The study only examined stream flow and therefore it is unknown how much rain may have been absorbed into the ground before it reached the streams. Examination of rainfall amounts along with discharge measurements (Figure 4.5) show days of high rainfall correspond to high levels of discharge for the most part. These effects are most notable for stream 3 which would be expected, as this is the larger stream with the greatest amount of land draining into it.

A sample of the rainfall from July 5th was taken and analyzed for nutrient concentrations. The concentrations were as follows:

Phosphate 4.90 μg/L
Nitrate 117.40 μg/L
Nitrite 2.25 μg/L

These values are low compared to values collected within the streams but it is important to understand that some background levels are contributed from the rainfall itself.

4.3 Hydrology

There are three main streams within the Basin Head Watershed (refer to Figure 3.4). There are additional small streams but they are frequently dry and therefore would not have much influence on the inputs to the Basin Head Lagoon, especially during the summer field season. There was no previous record of stream flow in the area but discussion with researchers and local people determined that no flow in these smaller streams is a common occurrence. 90° V-notched weirs were established at each of the three larger streams in order to monitor discharge throughout the summer. They were monitored on a weekly basis to note changes in discharge during the summer (Figure 4.3).

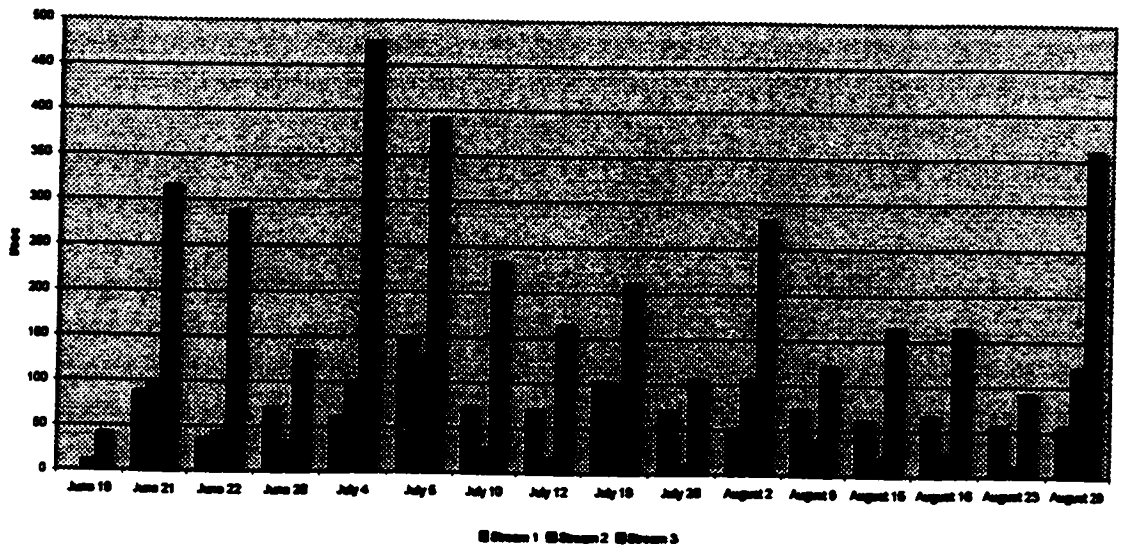


Figure 4.3 Stream Discharge During Summer of 2000

Discharge on stream 3 was always higher because the stream was of a larger magnitude than the other two that were monitored. For this reason the mean, minimum, maximum, and standard deviation were also graphed to show the differences in flow for the three streams (Figure 4.4).

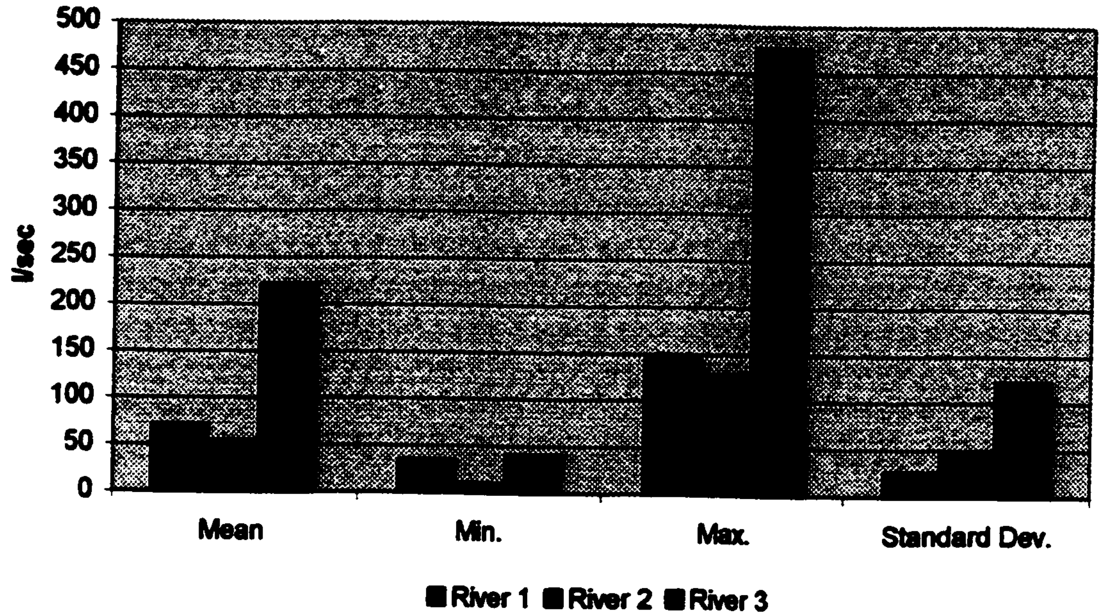


Figure 4.4 Average Discharge of Streams

The highest level of discharge for both streams one and two occurred on July 5th with levels of 145 l/sec and 128 l/sec respectively. For stream three the highest discharge occurred on July 4th at 475 l/sec. The lowest level of discharge on stream 1 occurred on June 22nd when flow was 34 l/sec. The lowest levels of discharge on streams 2 and 3 occurred on June 19th and were 9 l/sec and 40 l/sec respectively. There was no discharge value available for stream 1 on June 19th and this may be the reason why this day was not the day of lowest discharge shown. Discharge peaks occurred throughout the summer and for the most part occur during rainfall events such as the case with July 4th and 5th (see Figure 4.5). Although other days of high discharge that had no rainfall, such as August 29th, did occur throughout the field season for no apparent reason. This mainly

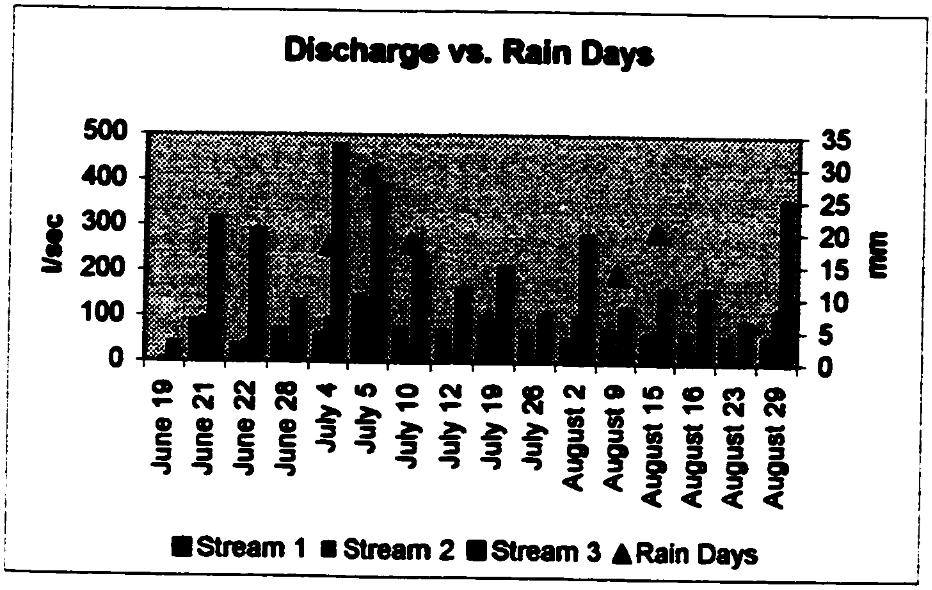


Figure 4.5 Discharge vs. Rainfall Days

occurred on stream three and a possible explanation may be an outfall going into stream three from a nearby potato factory but this was not confirmed. Figure 4.6 is a graph of the compiled stream discharge showing the approximate total freshwater discharge per second during sampling days.

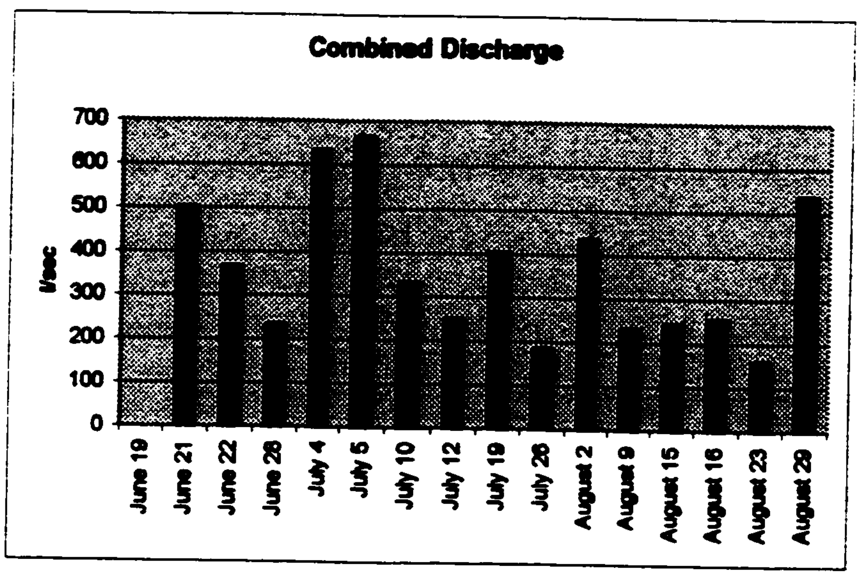


Figure 4.6 Freshwater Inputs From Streams Combined

June 19th values for discharge were omitted because it would have skewed results, as values were only available for streams 2 and 3. July 5th had the largest total discharge of 663 l/sec, while August 23rd was the smallest amount with 157 l/sec. Table 4.2 below summarizes discharge information and also includes the values of seasonal averages from all of the measurements collected throughout the field season.

Stream 1			
l/sec	High	Low	Seasonal Average
	Jul-05 145	Jun-22 34.1	71

Stream 2			
l/sec	High	Low	Seasonal Average
	Jul-05 128	Jun-19 9	53.9

Stream 3			
l/sec	High	Low	Seasonal Average
	Jul-04 475	Jun-19 40	220.3

3 Streams Combined			
l/sec	High	Low	Seasonal Average
	Jul-05 663	Aug-23 157	360.2

* June 19th not included in combined

Table 4.2 Discharge Values From Streams

4.4 Suspended Solids

Suspended solids were monitored at the same time that nutrient collection was completed therefore data are available for instantaneous levels within each of the three streams. The suspended solid data are summarized in Table 4.3.

Stream 1 mg/l	High	Low	Seasonal Average	Seasonal Standard Deviation
	Aug-23 171.8	Jul-04 12.1	42.1	3.3

Stream 2 mg/l	High	Low	Seasonal Average	Seasonal Standard Deviation
	Aug-15 236.1	Jul-04 12.3	97	20.1

Stream 3 mg/l	High	Low	Seasonal Average	Seasonal Standard Deviation
	Aug-16 145.5	Jul-04 17.1	48.3	6.1

3 Streams Combined mg/l	High	Low	Seasonal Average
	Aug-02 328.9	Jul-04 41.5	189

Table 4.3 Summary of Suspended Solid Data on Streams

Stream 2 had the highest level of suspended solids on August 15th and also had the highest average suspended solids over the season at 97 mg/l. Stream 1 had the lowest average at 42.1 mg/l.

Plots were developed to examine the relationship between suspended solid concentration and discharge at the time of sampling (Figure 4.7).

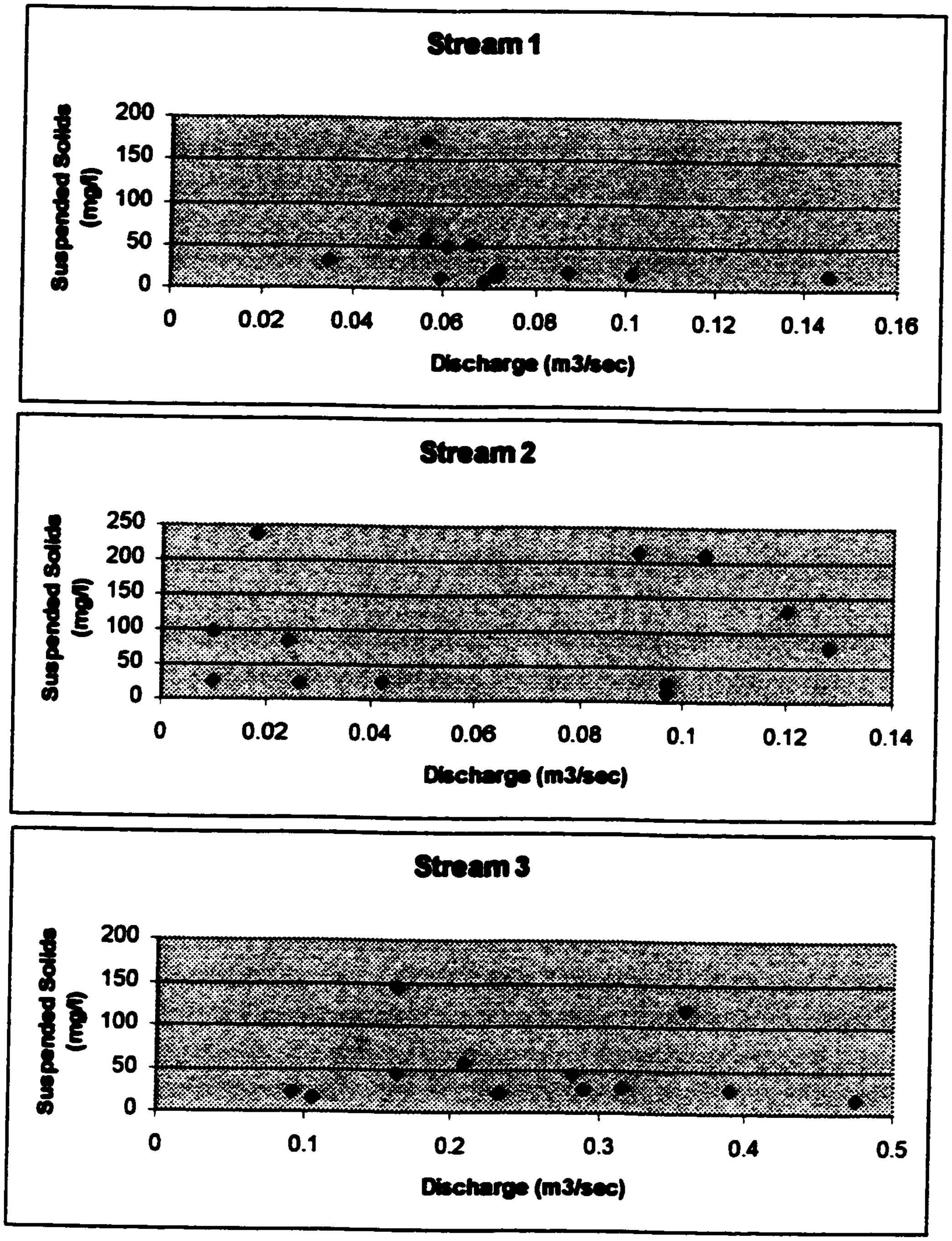


Figure 4.7 Suspended Solids Concentration Versus Discharge

The graphs show that there is no relationship in any of the three streams between discharge levels and suspended solid amounts. This is interesting because Prince Edward Island is known for problems with high sedimentation in runoff (Day, 2000). It was observed throughout the field season that the rainfall events were not heavy storms, but more continuous rainfall over a period of time. This could in part explain why sediments in runoff were low. Low sediment levels also could be in part due to previous erosion management precautions such as riparian buffer zones along each stream.

Additionally, sediment loads were calculated to examine how much actual sediment is entering the lagoon from the three streams. A summary of these loads can be seen in Table 4.4 below.

Stream 1 mg/sec	**High**	**Low**	**Seasonal Average**
	Aug-23 9.60E-03	Jul-26 5.60E-04	2.60E-03

Stream 2 mg/sec	**High**	**Low**	**Seasonal Average**
	Aug-02 2.20E-02	Jul-26 2.50E-04	6.70E-03

Stream 3 mg/sec	**High**	**Low**	**Seasonal Average**
	Aug-16 2.40E-02	Jul-26 1.80E-03	1.20E-02

3 Streams Combined mg/sec	**High**	**Low**	**Seasonal Average**
	Aug-29 6.20E-02	Jul-26 2.60E-03	2.10E-02

Table 4.4 Sediment Loads for All Streams

The values for sediment loads are all low for each stream. The highest load was on stream 3 on August 16^{th} at 0.024 mg/sec. It is no surprise that the highest load would come from stream three as it has the highest level of discharge out of the three streams. The values for the three streams were combined to obtain the average total load to the lagoon. The average sediment load from all of the streams is 0.021 mg/sec. From this it can be estimated that every hour, on average, there was 75.6 mg of sediment flowing into the lagoon. These discharge and sediment amounts will be used to examine the nutrient amounts being carried by the streams into the lagoon. First, it is important to examine how the lagoon is operating and which nutrient levels dominate the system.

4.5 Physical Properties

The Basin Head Lagoon itself consists of a water basin that is approximately 760m long and 380m wide with a channel, 500m long, connecting it to the Northumberland Strait. A long narrow arm extends 3 km east of the basin that is approximately 100-130m wide. The lagoon has a small opening that allows seawater to enter and therefore results in the lagoon being affected by tidal influences (refer to Figure 3.1). A bathymetric survey was conducted within the lagoon to obtain a general idea of the depths of the lagoon floor. No such survey had previously been conducted within the basin, as far as could be determined in a literature search or from talking with government employees. The bathymetry was completed using depth measurements that were corrected for tidal effects. An example of tidal measurement can be seen in Figure 4.8 where a 13-hour monitoring of tidal level within the basin was completed.

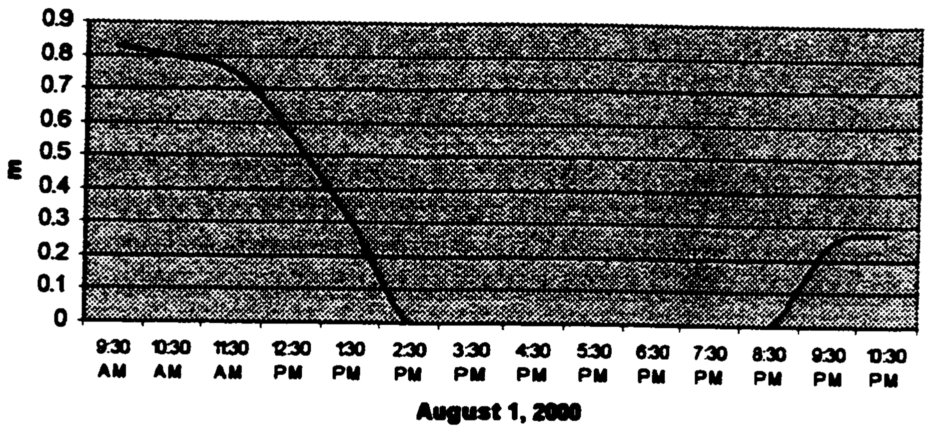


Figure 4.8 Tidal Cycle For Basin Head Lagoon

The collected depth measurements after correction were used to produce a bathymetric map of the Basin Head Lagoon. The placement of depths on an outline of the lagoon was completed from descriptions of the environment that were noted along with location coordinates obtained from a Garmin hand held GPS unit during the data collection. Therefore it is noted that there may be some error in the final bathymetric map, as error could have been introduced either from the outline map obtained from an outside source or from depth placements on the map. The GPS unit had a horizontal accuracy of +\- 10m, which in this situation is relatively large; therefore, physical descriptions were also used for location identification. A TIN (Triangulated Irregular Network) was produced to obtain values for surface area and volume of the lagoon at low tide, which were approximately $0.56km^2$ and $254\ 280m^3$. Values for lagoon volume were also calculated for high and average tide by using an average value for high (1.4m) and average (1.06m) tides throughout the sampling period from tide tables obtained from Fisheries and Oceans Canada (2000). The volume of the lagoon at high tide was found to be approximately $10.39 \times 10^5\ m^3$ and the average lagoon volume was approximately $8.48 \times 10^5\ m^3$. The

TIN also enabled lagoon volumes to be estimated during sampling times, which will be discussed further in the section dealing with chemistry. The TIN was then used to develop a grid with contours in order to produce the final bathymetric map (Figure 4.9). Pits of depth on the bathymetric map actually represent a channel flowing through the basin. They are represented as pits because of the interpolation technique used in ArcView. In order to remove these more depth measurements need to be collected in the area.

Hydrologic residence time (or flushing time) of the Basin Head Lagoon was a necessary component to identify, as this would give an indication of how much effect the stream inputs were having on the lagoon environment. Salinity differences within and outside the lagoon were an important component in identifying residence time as they are used to quantify the amount of freshwater within the lagoon. Salinity was collected during sampling throughout the basin and on the ocean for six separate occasions throughout the field season. The results of this collection for both the ocean and lagoon can be seen in Appendix B. Residence time was calculated for the lagoon during the six days that salinity values were measured both inside and outside the lagoon. The following equations were used to obtain residence time:

$$R + V_{in} = V_{out}$$

$$V_{out} = R / \left\{ 1 - \frac{S_{in}}{S_{out}} \right\}$$

And,

$$V_{in} = V_{out} \frac{S_{in}}{S_{out}}$$

Where, R = Stream Discharge Rate, V_{in} = Inflow Amount, V_{out} = Outflow Amount, S_{out} = Ocean Salinity Levels, and S_{in} = Lagoon Salinity Levels. Solving for V_{out} and V_{in} gives amounts in m^3/sec for the amounts flowing in and out of the system. To attain a time value for residence the following equation was used:

$$\text{Time (Days)} = \frac{\text{Volume}}{V_{in}}$$

(B.Petrie, personal communication, March 15, 2002)

The six days were examined and the following residence times were found (see Table 4.5).

	Stream Discharge (R) m3/day	Lagoon Volume (V) m3	Lagoon Salinity (Sin) ppm	Ocean Salinity (Sout) ppm	Outflow (Vout) m3/day	Inflow (Vin) m3/day	Time (Days)
July 26, 2000	15811.2	254279.8	22	29	65503.5	49692.3	5.12
August 3, 2000	37497.6	254279.8	28	31	387475.2	349977.6	0.73
August 8, 2000	19863.4	254279.8	25	30	119180.4	99317	2.56
August 9, 2000	19863.4	254279.8	23	30	85128.9	65265.5	3.9
August 23, 2000	13564.8	254279.8	22	30	50868	37303.2	6.82
August 29, 2000	46224	254279.8	28	32	369792	323568	0.79
Mean Residence Time	25470.7	254279.8	25	30	152824.2	127353.5	2
Upper Bound For Flushing (High Water)	25470.7	1038897	25	30	152824.2	127353.5	8.16

Table 4.5 Estimated Hydrologic Residence Time of Basin Head Lagoon

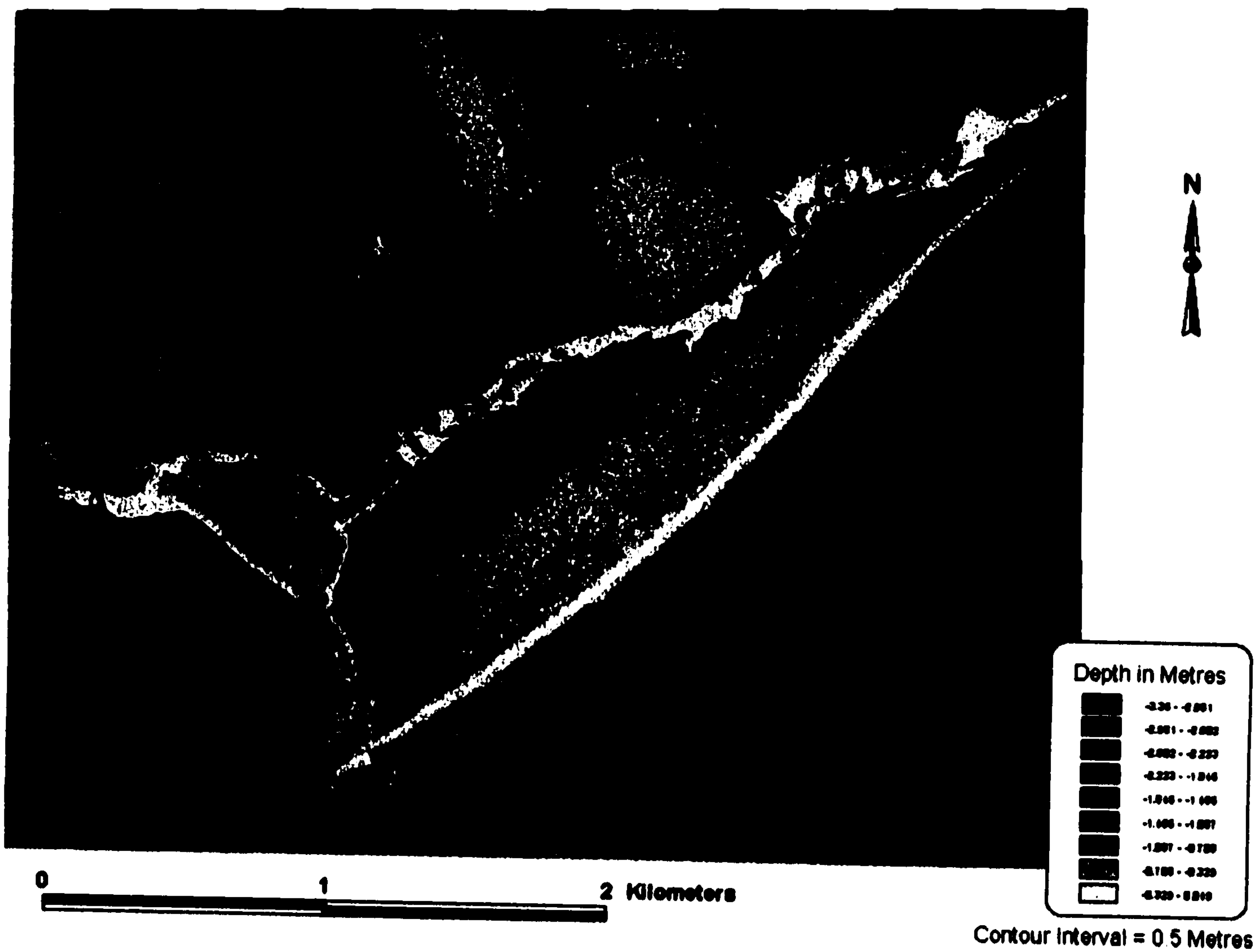


Figure 4.9 Bathymetry Map of Basin Head

The residence times varied from 0.73 – 6.82 days over the days examined. The mean residence time was calculated as 2 days. The upper bound for the longest residence time was measured using the volume of the lagoon at high tide. This was calculated to be 8.16 days for complete flushing during high tide phases.

The values obtained for the residence times can only be an estimate and are simply used to gain the understanding that the Basin Head Lagoon is an environment that has a relatively quick residence time. There are limited data available from the field season and therefore there is question about the reliability of the values used for mean salinity. Also, the residence time depends on many factors that could change with any given day such as strong tides, and strong winds. These factors could lead to a much shorter residence time than would be seen under normal conditions and the opposite for weak tides and little wind. Since there are minimal data for calculation of residence time little will be said about the numbers, except that it is evident that residence time within the Basin Head Lagoon is short. Therefore, ocean nutrient concentrations should have a profound effect. But first stream and lagoon nutrient concentrations will be discussed.

4.6 Stream Chemistry

Stream chemistry was one of the more important aspects of the study as no one had previously examined incoming nutrients from the streams. Four main nutrients were examined on each of the three streams, Soluble Reactive Phosphate (PO_4-P), Total Phosphorus (TP), Nitrate (NO_3-N), and Nitrite (NO_2-N). Figures 4.10 – 4.13 below show the relationship between nutrient concentrations and discharge levels. Figure 4.10 shows the phosphate concentrations on the three streams and their relationship with discharge. There appears to be no relationship between the two components although on stream 1 the highest level of phosphate occurs on the day with highest discharge, July 5th, and the lowest concentration occurs on the day with lowest discharge, June 22nd. It is important to recognize that the range for all three streams for phosphate concentration is between 19.9 and 85.8 μg/l. This is a very small range and does not seem to be influenced by changes in discharge.

The same cannot be said for total phosphorus, at least not for high concentration levels. High concentration levels were most notable on July 5th and July 19th this corresponds to high discharge levels on those days. July 5th was a rain period where it is possible runoff was a factor in the high TP concentration. July19th didn't have rainfall but examination of field notes shows that small amounts of rain fell on the night of July17th. The amounts were too small to warrant sampling, but perhaps this could have had some effect on both the nutrient levels and discharge found on July19th as there is no other apparent reason for the values to be high. The values for TP on stream 2 for these two days are highest at 159 μg/l and 387 μg/l.

Nitrate concentrations and discharge amounts show no relationship for all three streams. A similar pattern shows up in all three streams displaying low concentration levels at both the beginning and end of the season while concentration levels are high throughout the middle of the season. Nitrite concentrations for the three streams remain at the same level throughout the entire study period. Once again, the only day where the value increases is on July 19th for streams 2 and 3. But it is important to notice that although the values increase on this day it is not a large difference from the average values, approximately 10 μg/l. Table 4.6 shows a summary of the levels of nutrients found within each of the three streams.

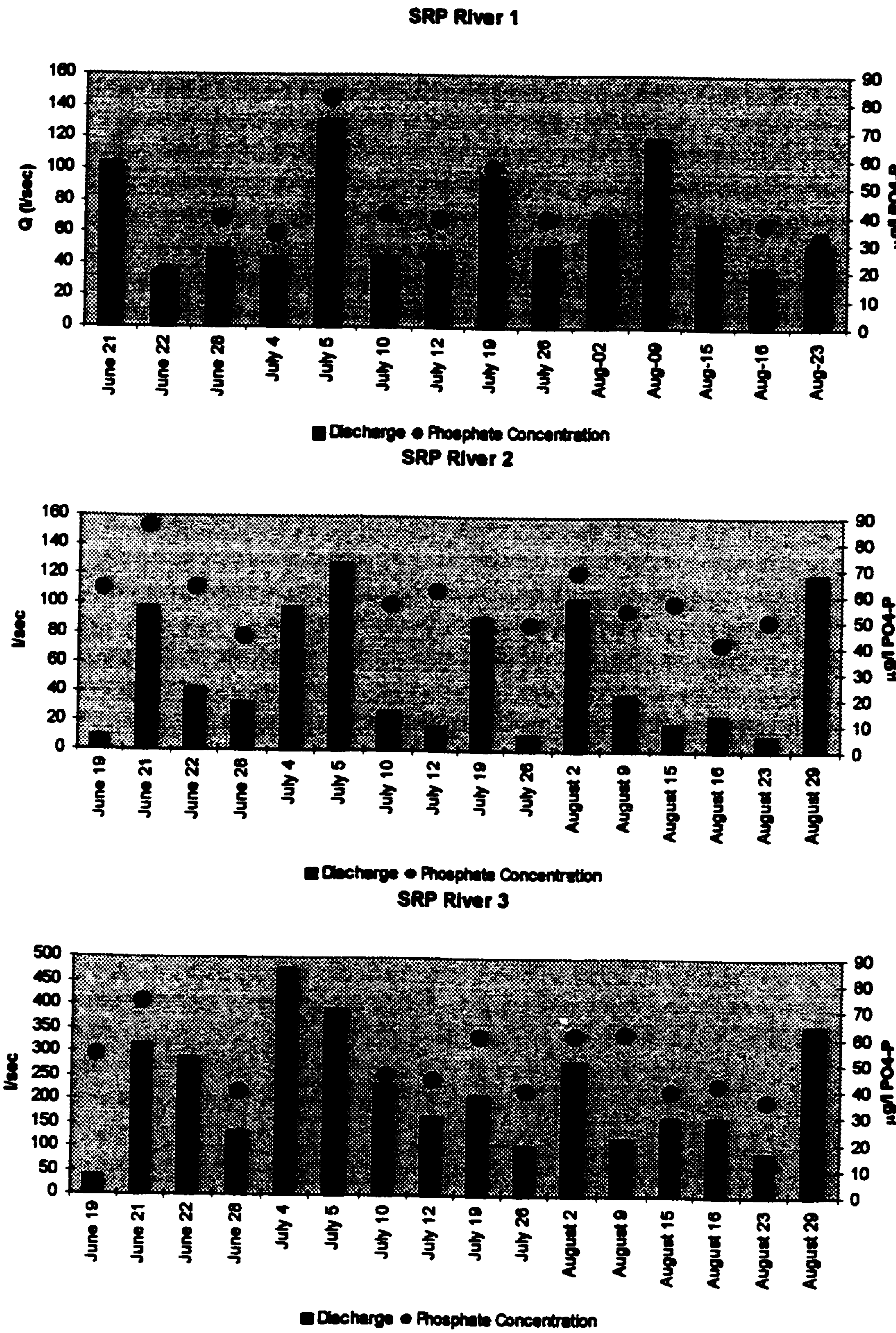


Figure 4.10 SRP Concentrations on the 3 Streams

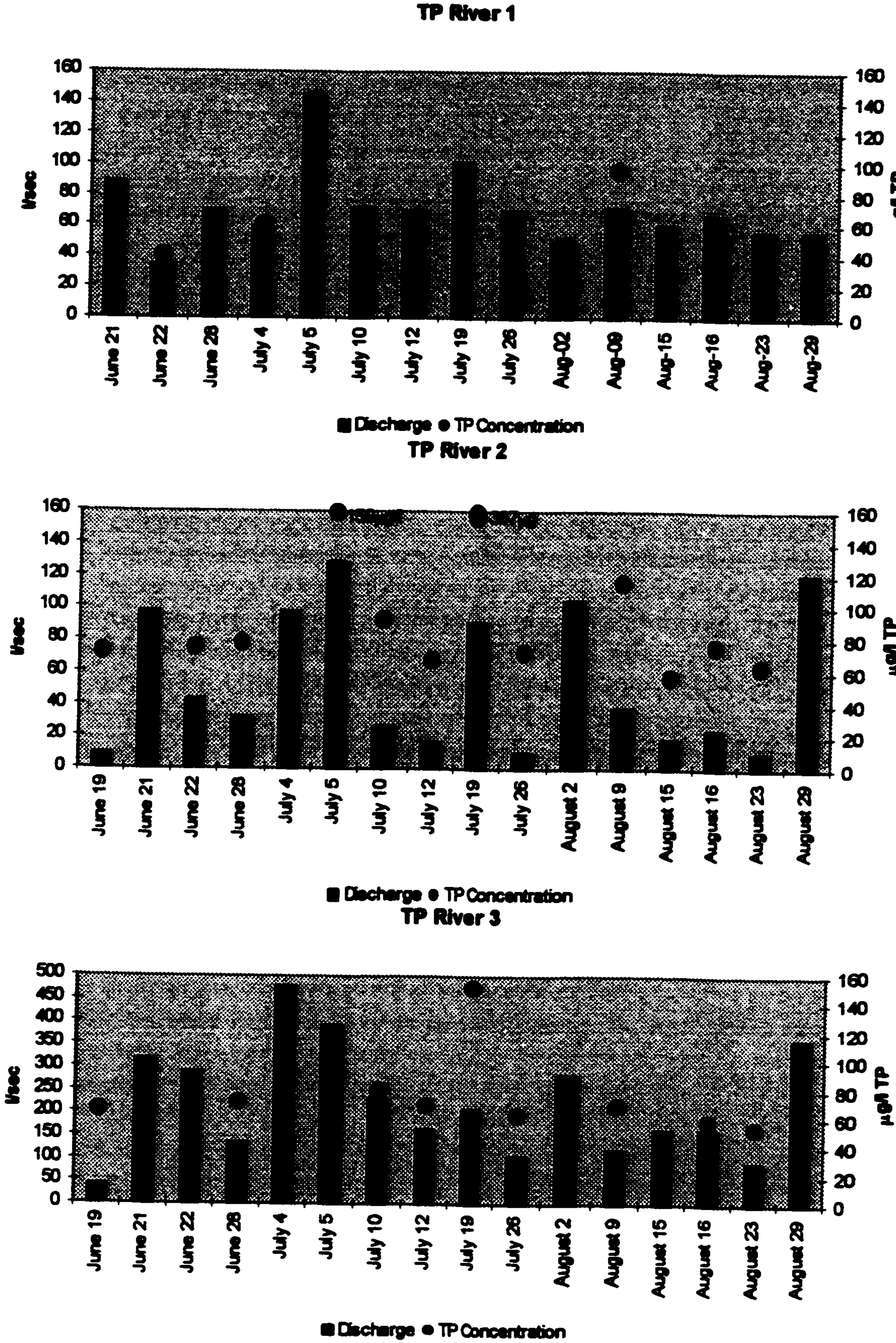


Figure 4.11 TP Concentration on the 3 Streams

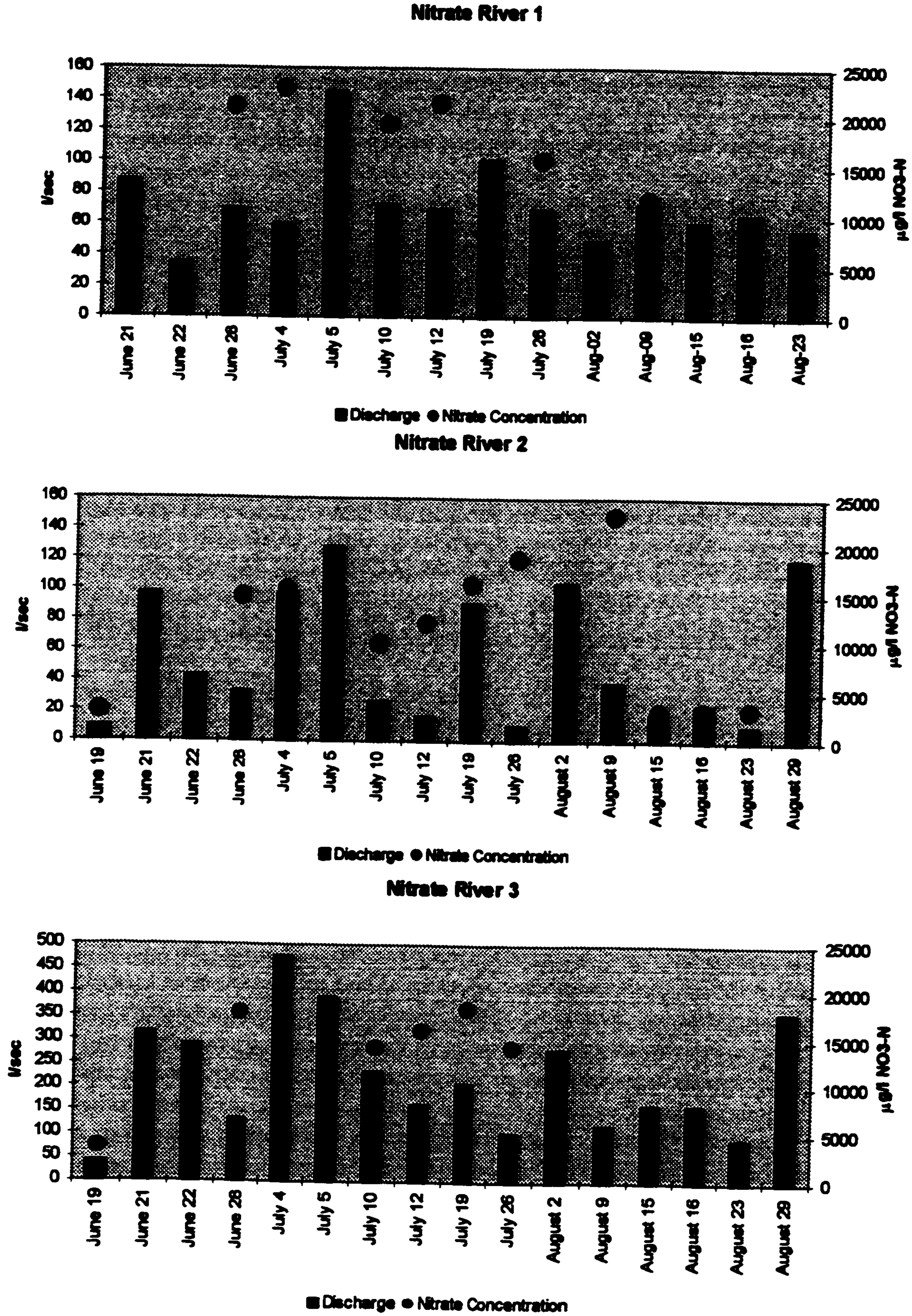
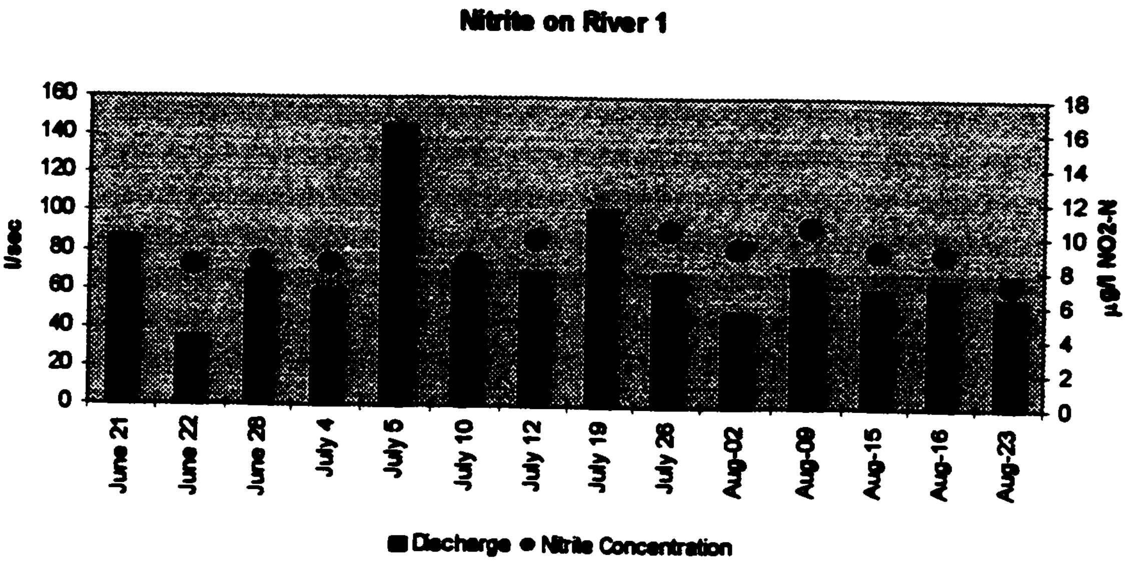
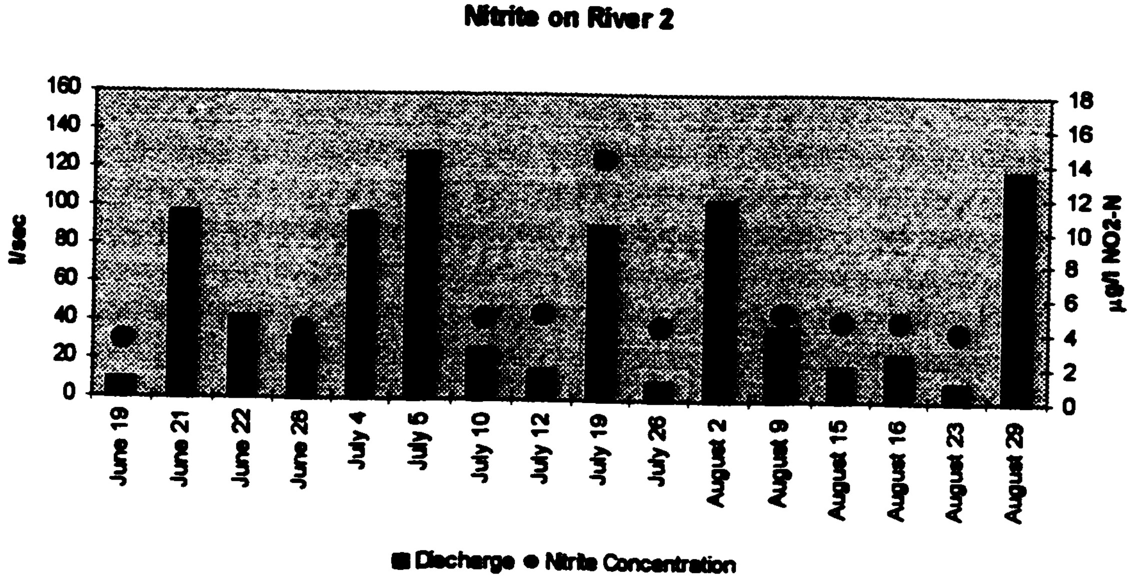


Figure 4.12 Nitrate Concentration on the 3 Streams





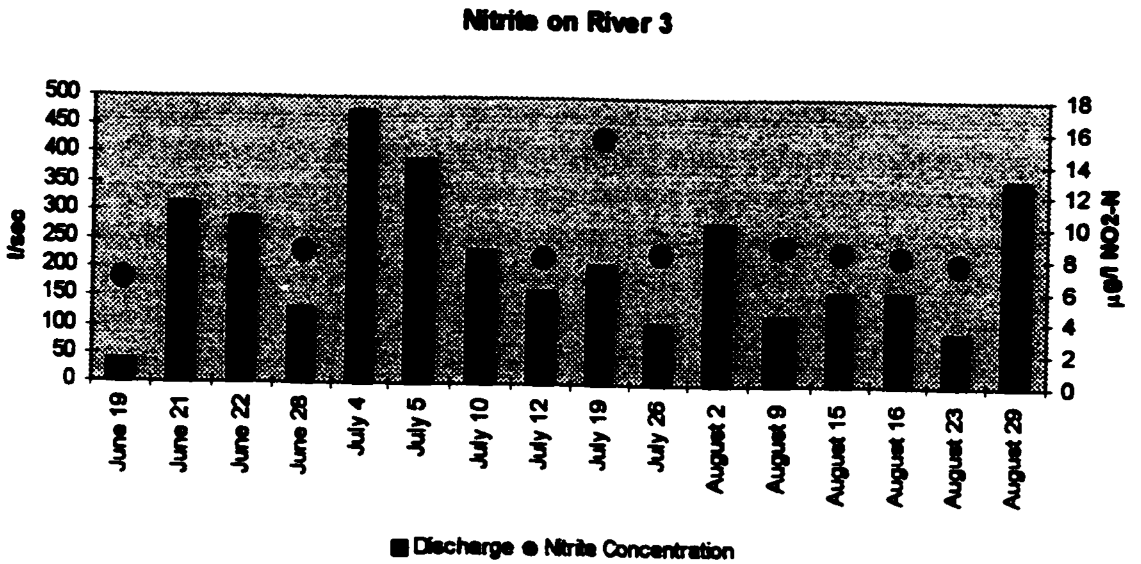


Figure 4.13 Nitrite Concentrations on the 3 Streams

Stream 1 µg/l	**High**	**Low**	**Seasonal** **Average**	**Seasonal** **Standard Deviation**
Phosphate	Jul-05 73.5	Jun-22 19.9	38.1	3.5
Nitrate	Jul-04 22918.7	Jun-21 4527.7	11077.4	154.2
Nitrite	Aug-09 10.5	Jul-05 6.5	8.6	0.2
Total Phosphorus	Jul-05 116	Aug-16 38	55.2	5.4

Stream 2 µg/l	**High**	**Low**	**Seasonal** **Average**	**Seasonal** **Standard Deviation**
Phosphate	Jun-21 85.8	Aug-29 30.6	51.8	2.7
Nitrate	Aug-09 23108.5	Jun-22 3049.8	9367	77.8
Nitrite	Jul-19 14	Jun-19 3.3	5.2	0.1
Total Phosphorus	Jul-19 387	Aug-29 53	98.3	3.1

Stream 3 µg/l	**High**	**Low**	**Seasonal** **Average**	**Seasonal** **Standard Deviation**
Phosphate	Jun-21 73	Aug-29 26.5	46.6	1.5
Nitrate	Jul-19 18295.2	Aug-09 3372.8	8773	881.9
Nitrite	Jul-19 15.5	Jun-19 6.6	8.5	0.1
Total Phosphorus	Jul-19 151	Aug-29 43	70.3	4.1

Table 4.6 Summary of Stream Chemistry

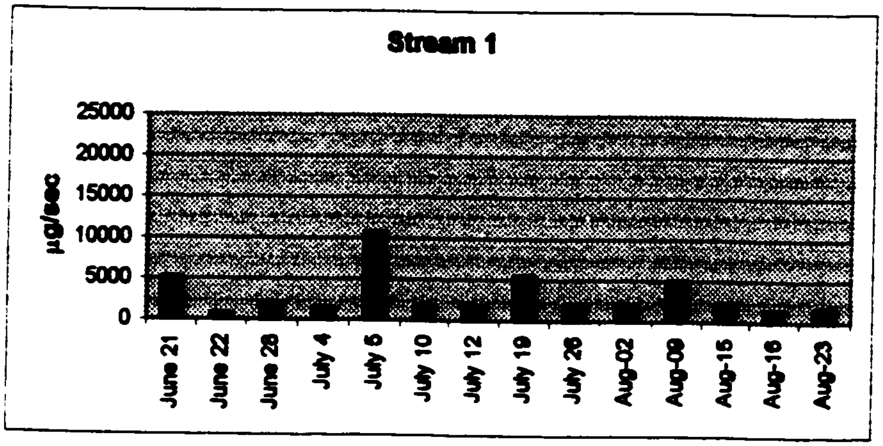
The average nutrient levels for phosphate in all three streams remain close at a level around 40 – 50 µg/l. Nitrate levels are higher in streams 1 and 2 at 11.08×10^3 µg/l and 9.37×10^3 µg/l respectively. Stream 2 also has the highest average concentration of total phosphorus at 98.3 µg/l. Average levels of nitrite are relatively equal for all three streams. Although it is important to note the range of actual values that are found within the stream, it is the mass flux of the nutrients being discharged from the streams that will provide more information on the stream affects on the lagoon.

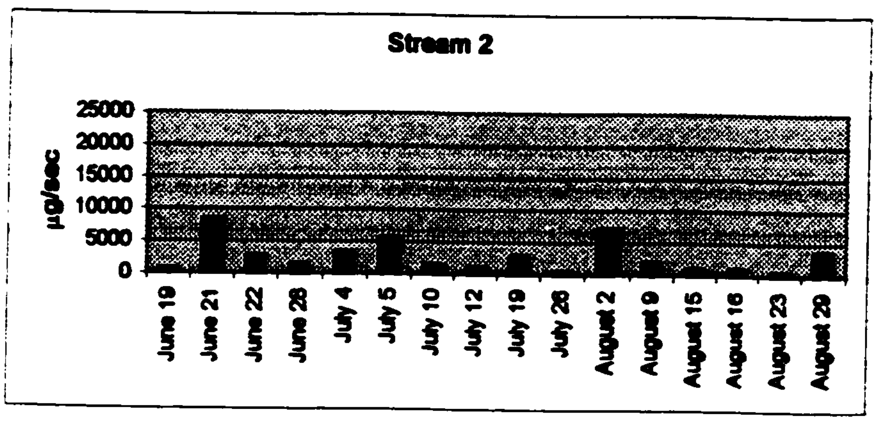
The mass flux levels are obtained by multiplying the concentration values of each nutrient by the discharge levels from each stream. This gives an amount in μg/sec being released from the streams into the lagoon. It is important to note that these values are only relevant for instantaneous moments of time when sampling was conducted. Later on a 24-hour cycle for inputs from stream 3 will give an example of what is happening on a daily basis.

Figures 4.14 – 4.17 show mass flux for all of the nutrients examined. The mass flux values for all nutrients are highest for stream three, as would be expected as discharge levels on this stream are much higher than stream one or two. The highest levels of phosphate appear on July 5th for streams one and three, which is also a day where rainfall occurred. Levels for stream two do not fluctuate as much as the others. Again, there seems to be little relationship between rainfall events and high levels of mass flux. This is no surprise as there was no relationship between rainfall and discharge either. It is evident from the mass flux data that stream three is most important for the input of nutrients into the lagoon. The total phosphorus values once again appear high on July 5th and 19th. Stream 1 unfortunately has no data for July 19th so it can't be confirmed that all streams had high levels on this day although the assumption seems highly possible.

Stream one, for the most part, has nutrient values that do not change much throughout the entire season. Stream two and three values seem to be affected more by the environment conditions than stream one. The nitrate values for all three streams show an increase in the middle of the season with low levels appearing in June and August. Table

4.7 summarizes the mass flux information obtained from the three streams. The values from all three streams at once were also shown to give an example of instantaneous total nutrient input into the lagoon.





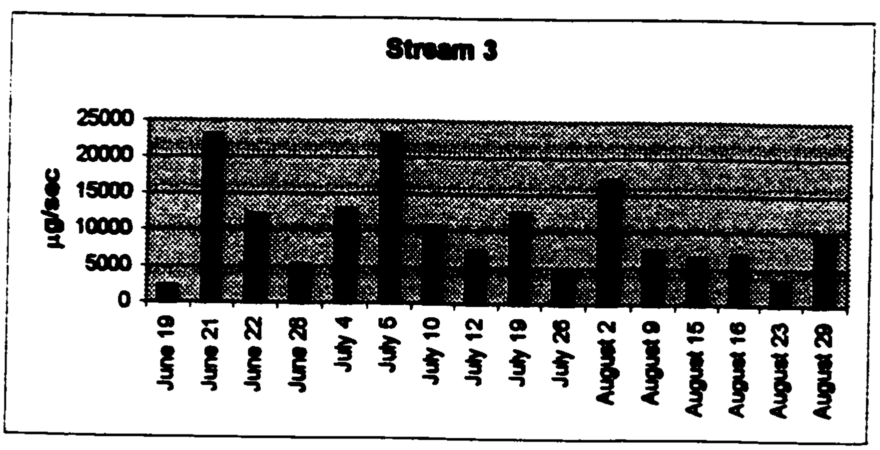


Figure 4.14 Mass Flux of Phosphate for the Three Streams

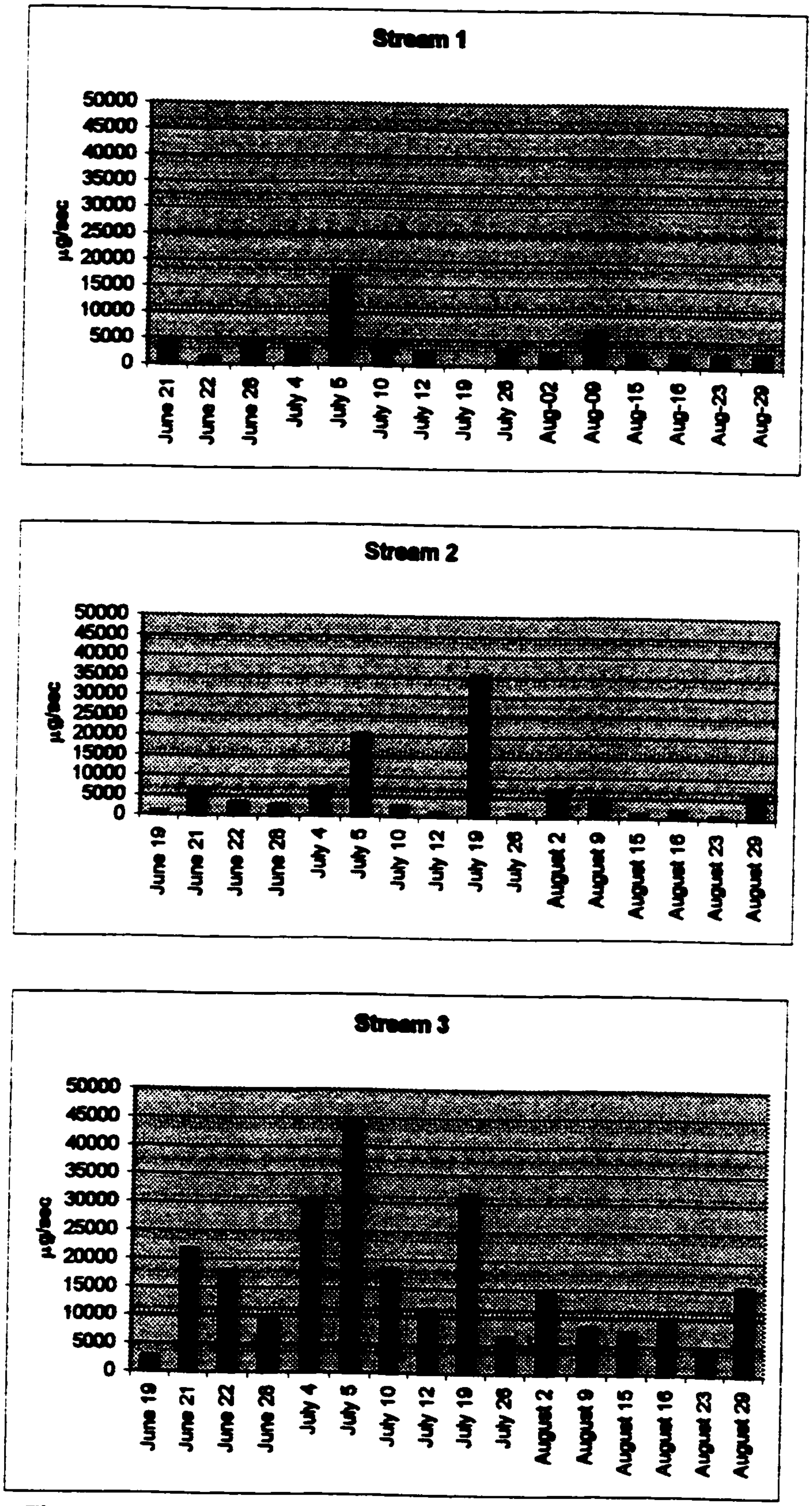


Figure 4.15 Mass Flux of Total Phosphorus for the Three Streams

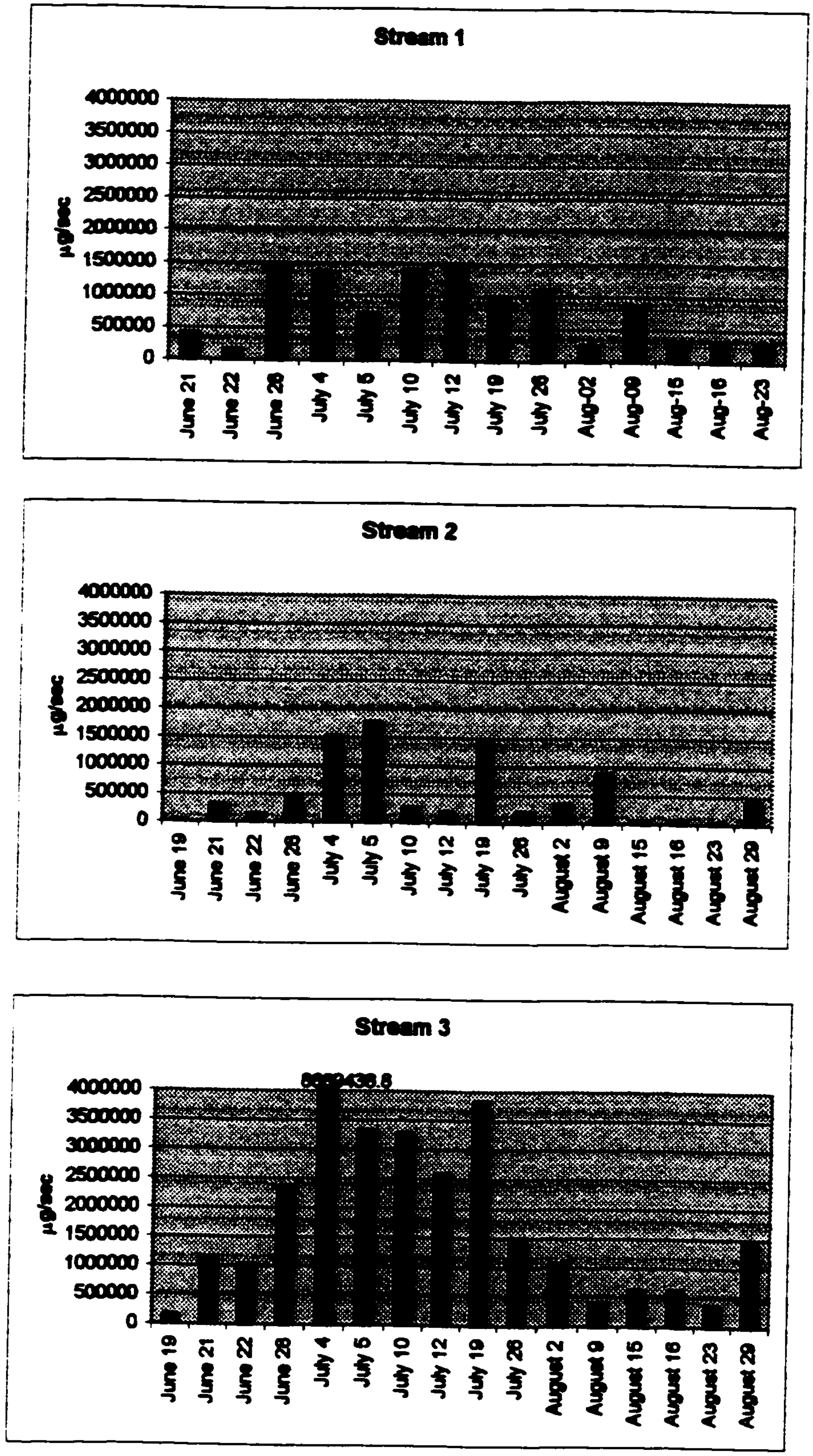


Figure 4.16 Mass Flux of Nitrate for the Three Streams

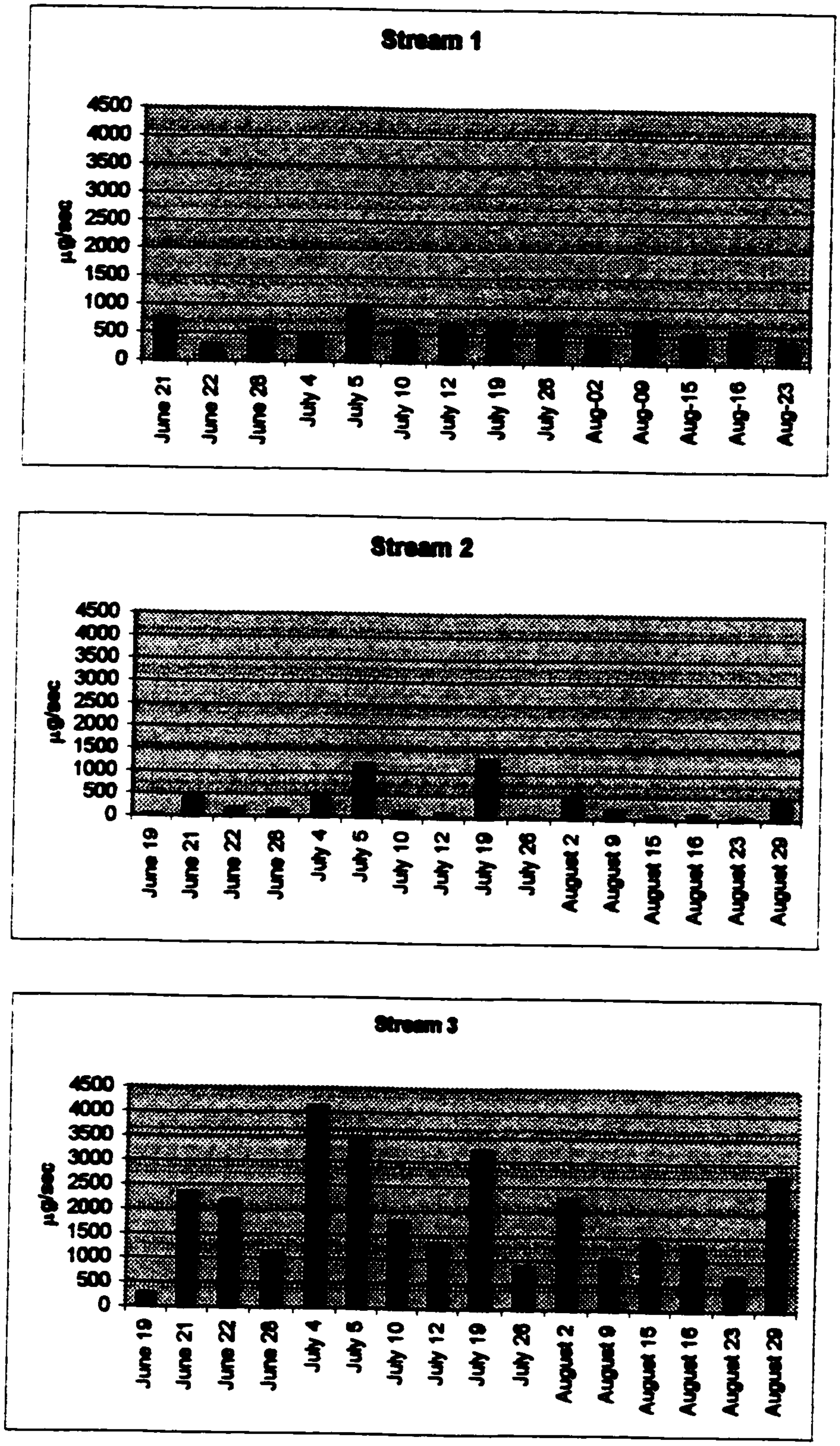


Figure 4.17 Mass Flux of Nitrite for the Three Streams

Stream 1 µg/sec	High	Low	Seasonal Average
Phosphate	Jul-05 10664.4	Jun-22 678.1	3068.5
Nitrate	Jul-12 1477303.8	Jun-22 154472.3	783168.7
Nitrite	Aug-09 756.5	Jun-22 278.1	604.3
Total Phosphorus	Jul-05 16820	Jun-22 1381	4288

Stream 2 µg/sec	High	Low	Seasonal Average
Phosphate	Jun-21 8324.9	Jul-26 483	2684
Nitrate	Jul-05 1753740.8	Jun-19 28021.1	506276.8
Nitrite	Jul-19 1278.5	Jun-19 29.8	321.7
Total Phosphorus	Jul-19 35217	Aug-23 640	6278.4

Stream 3 µg/sec	High	Low	Seasonal Average
Phosphate	Jul-05 23098	Jun-19 2114.8	10163.2
Nitrate	Jul-04 8669438.8	Jun-19 147120.4	2017011.4
Nitrite	Jul-04 4103.1	Jun-19 262.4	1879.3
Total Phosphorus	Jul-05 44655	Jun-19 2620	15840.1

3 Streams Combined µg/sec	High	Low	Seasonal Average
Phosphate	Jul-05 39383	Aug-23 5460.3	15532.1
Nitrate	Jul-04 11544860.5	Aug-23 671802	3208560.7
Nitrite	Jul-05 5556.2	Aug-23 1141.3	2729.8
Total Phosphorus	Jul-05 81827	Aug-23 7759	25763.5

Table 4.7 Summary of Mass Flux Data

Table 4.7 shows the high and low values from each stream and also the average level coming from each stream from the data collected over the season. Table 4.7 for the three streams combined was constructed to show how much in total was being put into the lagoon by all streams. It is important to emphasize that data for June 19th were ignored, as there was no level recorded for stream one. This may have been the day for lowest levels recorded, but this can't be confirmed, so table 4.7 shows the day with the next lowest level for each stream. Data for July 19th on stream one for total phosphorus were also not available and therefore not included, but by examining the information from the other streams on this day, it appears that it is probable levels were high. The most important information from the combined nutrient values is the averages over the season as it gives some idea of the mean amount of nutrients being exported to the lagoon.

4.7 24 Hour Survey

This information shows the types and levels of nutrients being brought into the lagoon from the freshwater environment throughout the study period. These levels show the amounts at an instantaneous point in time. On August 21 and 22 stream three was monitored for a continuous 24-hour period. Sampling was conducted for nutrients, discharge, and suspended solids. The conditions prevalent throughout this time period were considered to be normal conditions, meaning sunny skies and no rainfall amounts previous to or during sampling. Table 4.8 summarizes the nutrient values, discharge, and suspended solid levels over the 24-hour period. These values were compared to the seasonal averages obtained on stream three throughout the study period. Average levels obtained for phosphate and nitrite were the same for both the 24-hour study and the seasonal average on stream three at 49.5 and 8.1 μg/l respectively.

	µg/l				l/sec	mg/l	mg/day
Time	PHOSPHATE	NITRATE	NITRITE	TOTAL PHOSPHORUS	DISCHARGE	SUSPENDED SOLIDS	SEDIMENT LOAD
20:00	54.67	3863.30	7.31	55	66	23.85	136.02
21:00	36.44	3937.99	7.85	70	66	34.49	196.69
22:00	36.70	3644.20	7.43	62	66	34.83	198.62
23:00	56.62	3944.22	8.09	55	66	27.99	159.59
0:00	38.97	3907.89	8.19	51	66	17.24	98.32
1:00	47.45	3914.89	8.30	46	120	42.80	443.80
2:00	43.82	3921.05	7.96	45	198	25.32	433.09
3:00	44.73	3964.45	7.77	48	226	24.42	476.89
4:00	48.81	3979.22	8.26	43	198	27.67	473.32
5:00	47.88	3958.22	10.21	43	149	18.68	240.46
6:00	39.29	3954.30	7.96	41	112	25.45	246.32
7:00	50.45	3951.99	7.83	57	91	17.70	139.19
8:00	49.83	4002.60	8.38	43	77	15.87	105.60
9:00	45.40	3911.46	8.36	42	66	22.85	130.33
10:00	53.46	3870.93	7.89	48	93	20.16	162.00
11:00	43.51	3939.39	7.76	44	81	24.27	169.88
12:00	43.31	3874.50	7.81	37	78	17.62	118.75
13:00	122.92	3922.10	8.30	51	71	29.17	178.94
14:00	45.60	3990.21	7.95	47	72	11.54	71.78
15:00	58.87	3958.01	8.84	46	84	22.25	161.48
16:00	41.79	3963.47	7.89	59	91	11.54	90.72
17:00	48.34	3876.39	7.57	50	87	23.48	176.53
18:00	45.43	3868.27	7.00	104	65	16.53	92.83
19:00	44.22	3921.54	7.35	52	66	16.17	92.22
20:00	49.29	3916.08	9.82	49	72	27.89	173.49
Total	1237.79	97956.67	202.12	1288	2427	579.81	4966.87
Average	49.51	3918.27	8.08	51.52	97.08	23.19	198.67
Standard Deviation	12.6	78.6	0.6	n/a		9.6	

Table 4.8 Summary of Results Obtained During 24 Hour Sampling of Stream 3

Levels for nitrate and total phosphorus are lower during the 24-hour survey at 3918.3 and 51.5 µg/l. This could in part be due to the fact that there was rainfall during the season that appears to have had more of an impact on the levels of nitrate and total phosphorus, yielding higher levels throughout the season.

Mass flux was also calculated for the nutrients during the 24-hour period on stream 3 (Figure 4.18). These graphs show that there was a peak in all nutrient levels at approximately 3:00 AM and phosphate showed another peak at 1:00 PM. These graphs show that nutrient level discharge does not remain constant over a 24-hour period. It is unclear at this time why there is a peak in nutrient levels. Discharge on stream 3 was measured above the limit of tidal influence, which was checked with a salinometer at the weir. Tidal levels at this time of year were also at a low, which would reduce the risk of tidal influence even more (see Appendix C).

The sediment concentrations (mg/l) were graphed against discharge (m^3/sec) to see if any relationship existed over the 24-hour period (Figure 4.19). It is obvious from the graph that there is no relationship between the two for stream three during this period.

From the information obtained in the 24-hour study total nutrient amounts, sediment loads, and discharge carried into the lagoon from stream 3 were calculated (Table 4.9). This gives an idea of what the amounts are that get carried into the lagoon from stream three on a daily basis.

MASS FLUX (grams)				cubic meters	mg
PHOSPHATE	NITRATE	NITRITE	TOTAL PHOSPHORUS	DISCHARGE	SEDIMENT LOAD
425.18	34315.08	71.13	434.24	8737.2	208.95

Table 4.9 24-Hour Totals of Inputs to the Lagoon, Aug. 21 & 22

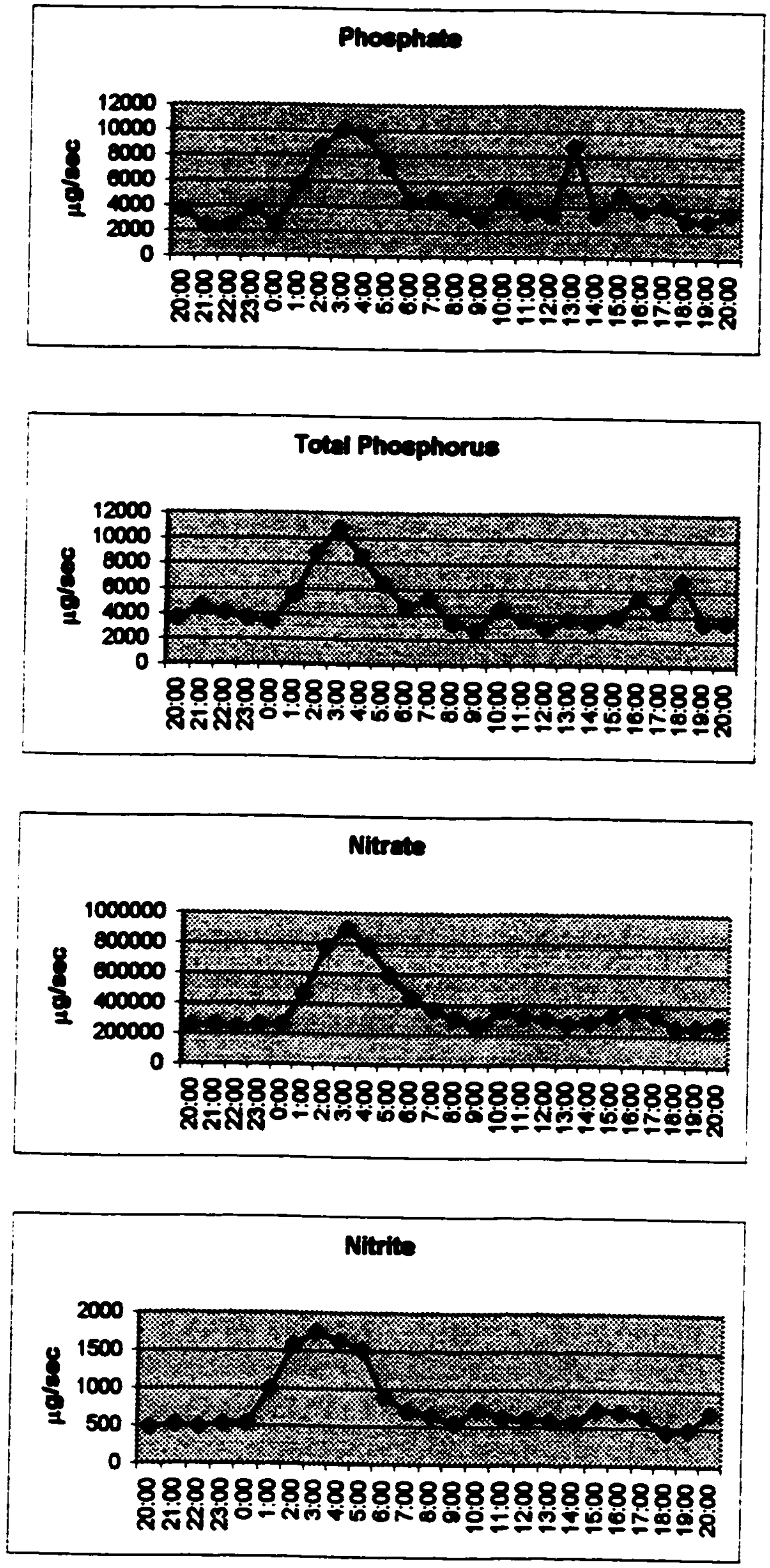


Figure 4.18 Mass Flux Nutrient Levels on Stream 3

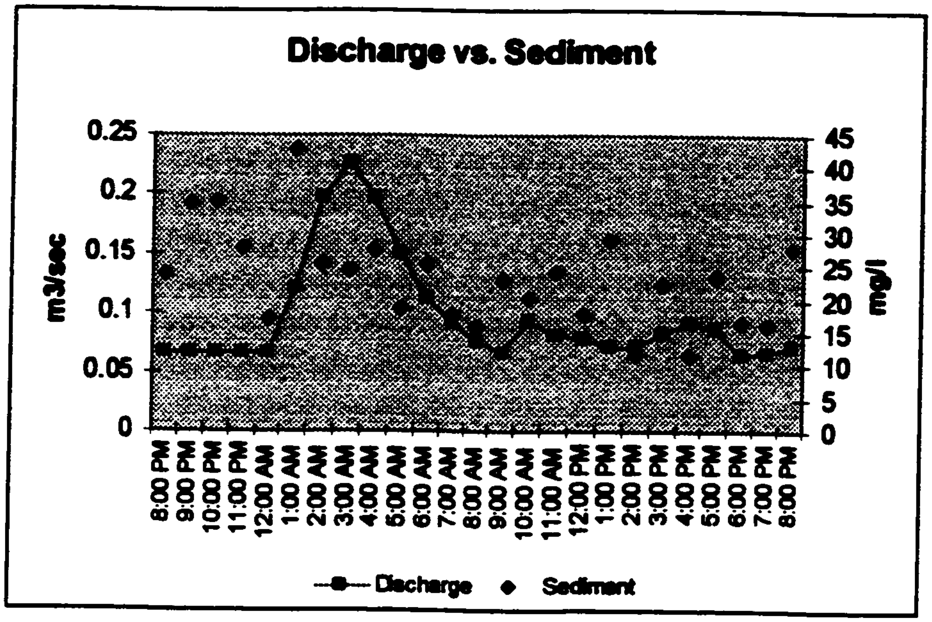


Figure 4.19 Discharge vs. Sediment for Stream 3 Aug. 21 & 22

The above example of normal 24-hour inputs to the lagoon from stream 3 is very important in examining what is ongoing on a continuous basis within the stream environment and emptying into the lagoon. Over the 24 hour time period, stream three exported approximately 425 grams of phosphate, 34 315 grams of nitrate, 71 grams of nitrite, 434 grams of total phosphorus, 8737.20 cubic meters of water, and 207 milligrams of sediment into the lagoon.

4.8 Lagoon Chemistry

The nutrient concentrations within the lagoon were examined on a weekly basis to monitor changes in levels throughout the field season. The levels of phosphate, nitrate, and nitrite were examined at six locations throughout the lagoon. Figure 4.20 – 4.22 show the levels of each nutrient at all six locations within the lagoon

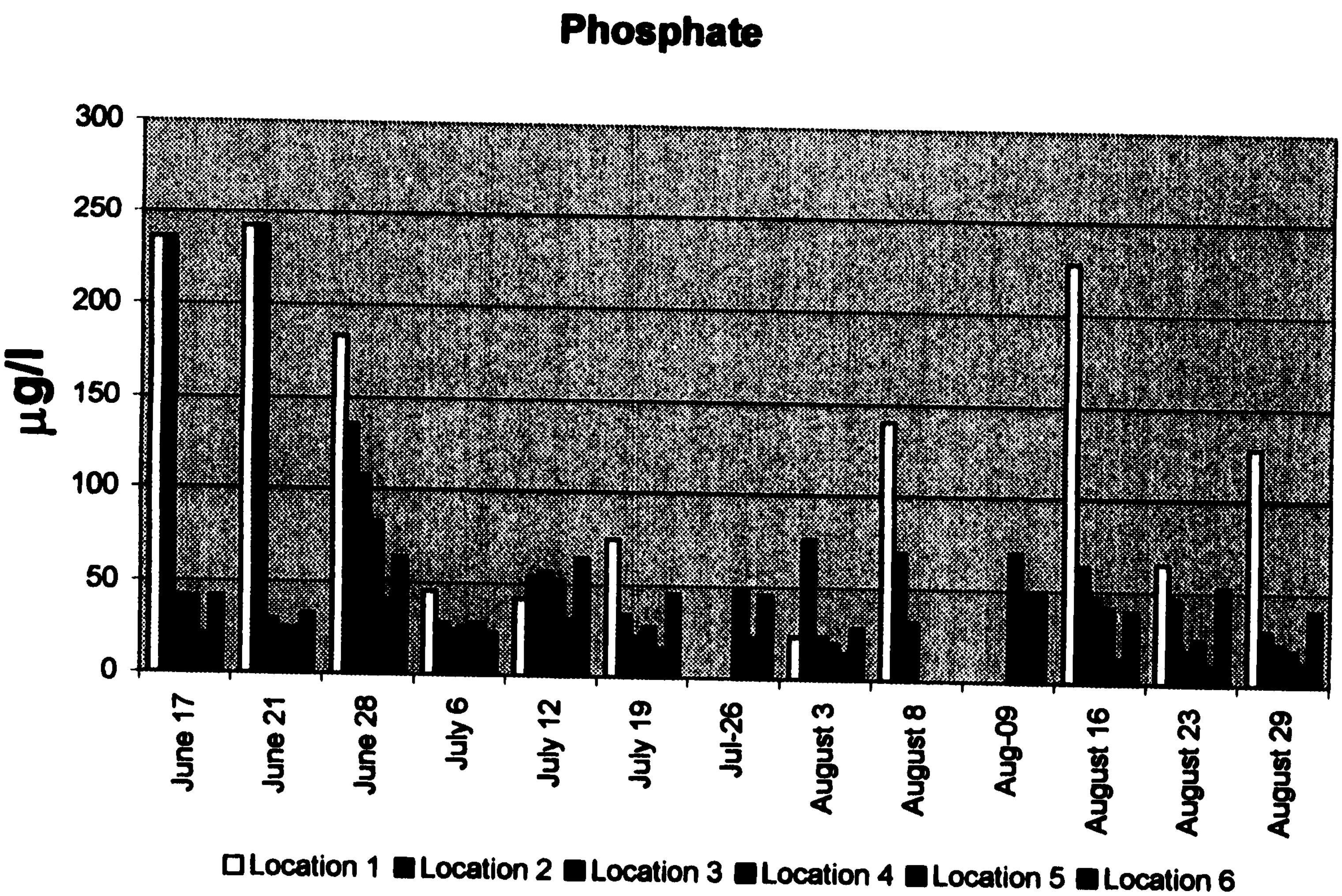


Figure 4.20 Phosphate Levels Within Lagoon

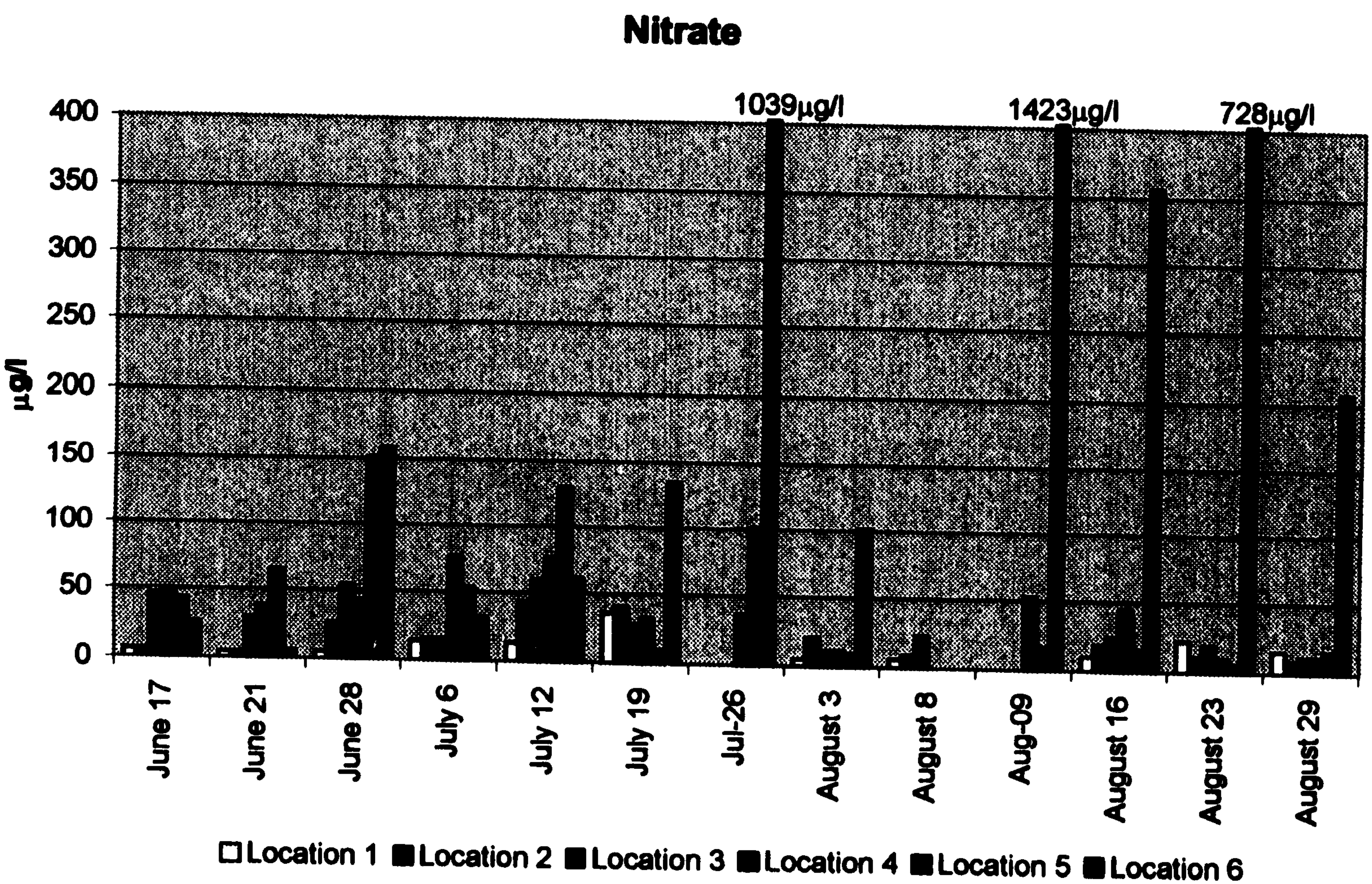


Figure 4.21 Nitrate Levels Within Lagoon

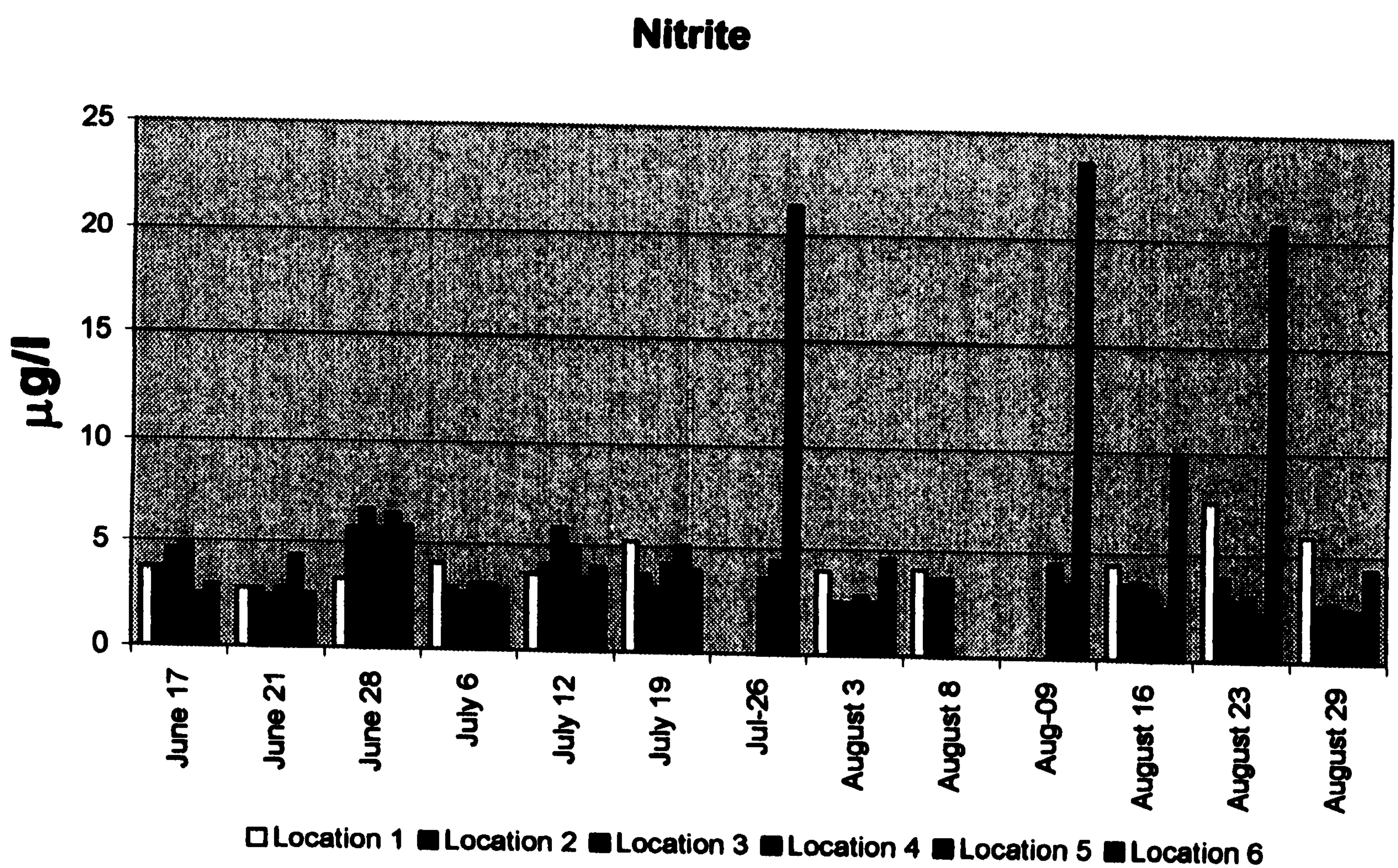


Figure 4.22 Nitrite Levels Within Lagoon

The levels were monitored throughout the lagoon in order to have a better understanding of what is occurring throughout the entire lagoon. For this study the nutrient levels at locations 1, 2, and 6 are though to be the most important. This can not be confirmed as more information is needed on the circulation patterns throughout the lagoon. Since this information is not available at this time locations 1, 2, and 6 will be the main focus. Location one is at the eastern end of the lagoon (refer to Figure 3.4) and is of interest because at certain times of the year the entire surface is covered with a mat of Ulva (Figure 4.23). Ulva is a small genus of marine and brackish water green algae. It can be a nuisance in areas that are nutrient enriched. Location 2 is nearby and is also the closest to stream 1 and 2 outlets. Location 6 is the nearest to stream 3 outlet. It will be these locations that tell the most about the stream impacts on the lagoon chemistry because they are closest to the stream outputs. The controlling circulation patterns within the lagoon appear to be tidal currents, which is evident from equal salinity levels at the mouth of the lagoon and the far end of the arm. Tidal circulation dominates the relatively small quantities of freshwater entering the lagoon.

Figure 4.23 Ulva Found at Location 6

The phosphate graph identifies the high levels found at locations 1 and 2. These locations both seem to show a trend of high values during June sampling and again in August. The nitrate graph shows low values around location 1 throughout the summer even when stream 1 has high nitrate concentrations emptying into the lagoon. This could be the reason there are high amounts of Ulva found in these areas. The Ulva may be absorbing the nitrates within the waters. Ulva have high nitrogen requirements for growth and thrive in areas where nutrient availability is high (Kirby, 2001). For the most part, phosphate values at location 6 remain constant throughout the study period. Nitrate and nitrite both show low levels at locations 1 and 2 throughout the season. July and August nitrate and nitrite levels at location 6 are very high.

When examining the lagoon chemistry it is important to remember the nutrient inputs from ocean loading. Since the Basin Head Lagoon has a very rapid flushing time, ocean nutrient levels would have a large effect on levels found within the lagoon itself.

4.9 Ocean Nutrient Levels

Ocean nutrient levels were obtained from the Department of Fisheries and Oceans for the study period of June, July, and August of 2000 from the ocean off of Shediac, New Brunswick. Table 4.10 below shows the average nutrient concentration found.

Average Nutrient Concentrations		
	μg/l	μg/l
Date	Nitrate	Phosphate
26-Jun	88.08	24.91
23-Jul	98.73	30.08
14-Aug	102.50	28.83
29-Aug	86.54	25.61

Table 4.10 Average Ocean Nutrient Concentration

Hydrologic residence time of Basin Head Lagoon was found to be low. Therefore, it is expected that lagoon concentrations should closely resemble those found in the ocean.

The ocean nutrient levels were graphed with the levels found throughout the lagoon for phosphate and nitrate (Figure 4.24 – 4.25).

Nitrate levels for locations 5 and 6 within the lagoon are mostly above the ocean nutrient concentration. There is a trend occurring where nitrate levels seem to be increasing for July and peak at the end of July and beginning of August. Levels throughout the remainder of the lagoon are near or below ocean nutrient concentrations. The ocean concentration stays around 90 μg/l throughout the season while lagoon concentration levels elevate up to around 1000 μg/l. Phosphate concentrations are also elevated when compared to ocean levels. The highest differences are seen in locations 1 and 2 during June and again in August. The normal value for ocean nutrient concentration is approximately 25 μg/l while the highest concentration levels found within the lagoon are around 240 μg/l. This shows evidence that the streams do have an impact on the lagoon chemistry but how much is still unknown. There could be nutrients being transported to the lagoon through groundwater transport, or other means such as outfalls from surrounding areas. Groundwater transportation may be likely as the soils surrounding Basin Head are mainly sandy and would have high permeability.

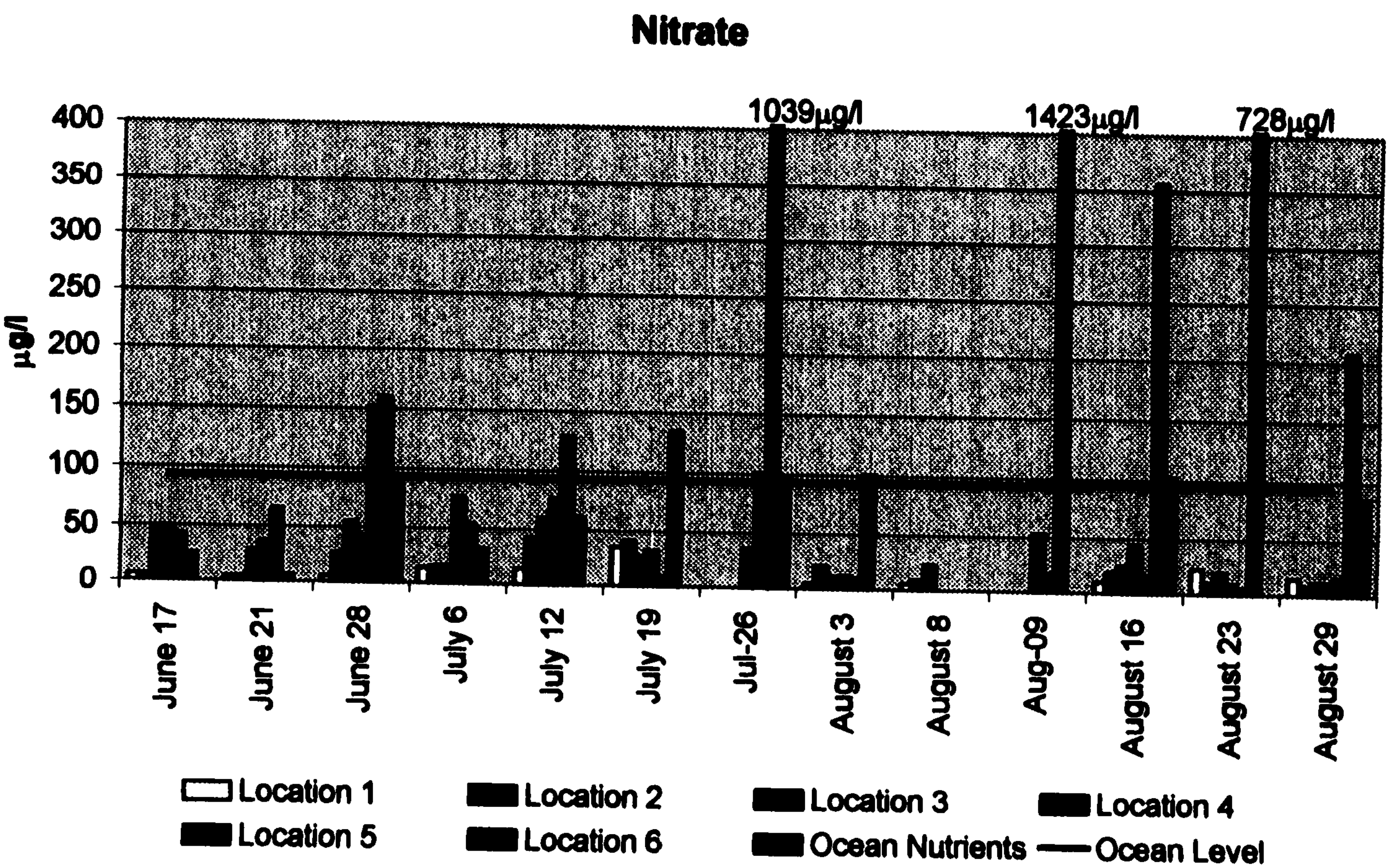


Figure 4.24 Nitrate Graph – Ocean Levels vs. Lagoon Levels

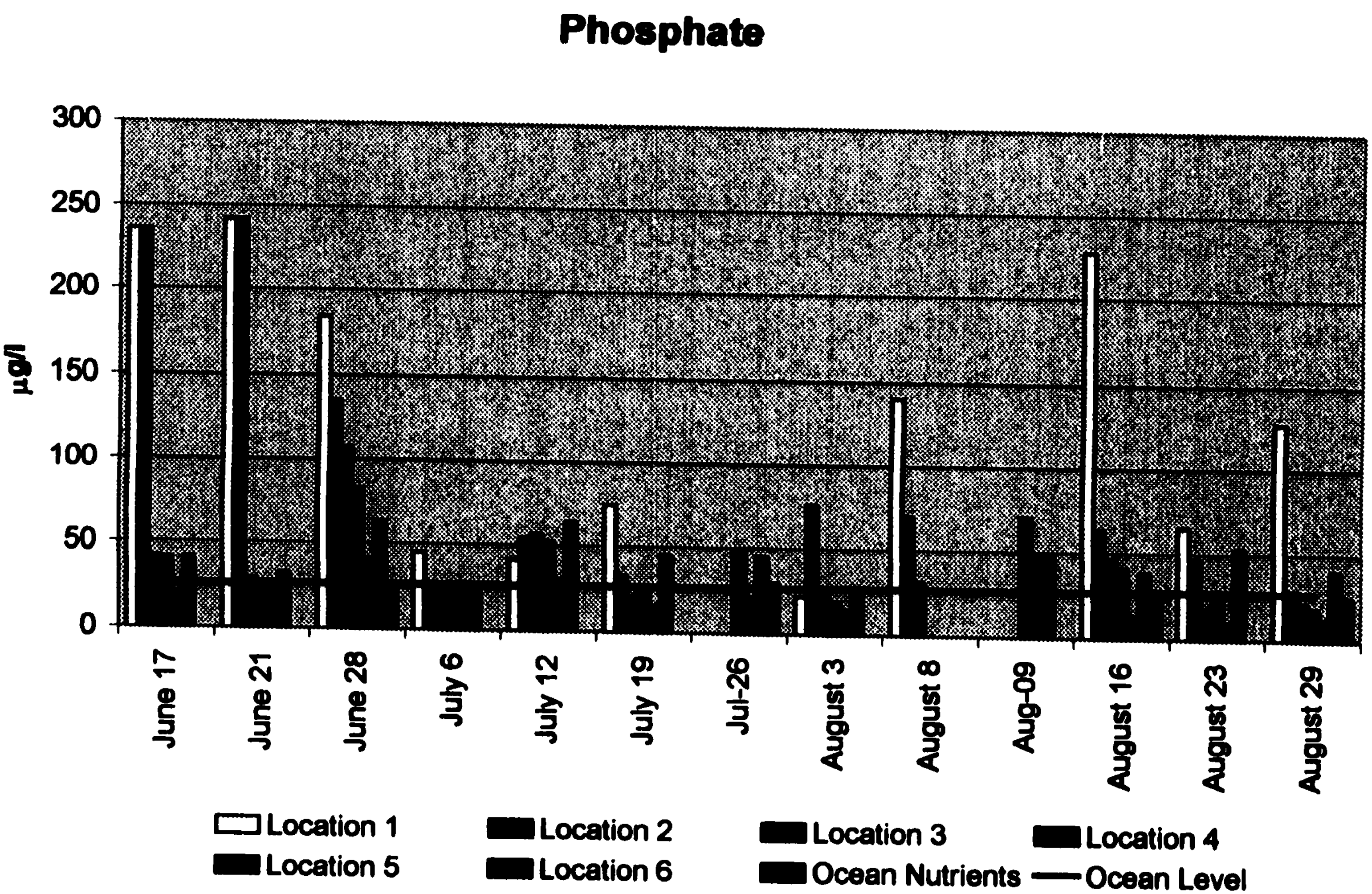
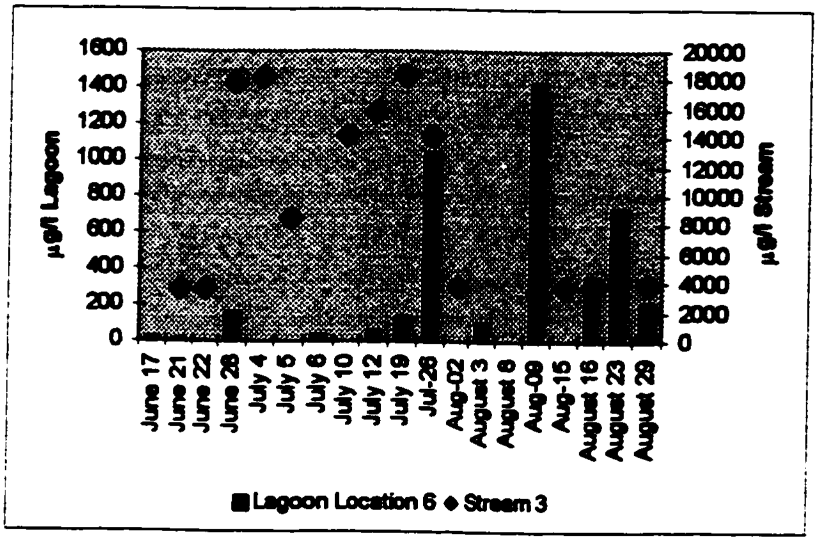


Figure 4.25 Phosphate Graph – Ocean Levels vs. Lagoon Levels

4.10 Stream Impact

In order to determine stream effects on the lagoon the relationship between nutrient levels at lagoon locations 1 and 2 were graphed against stream 1 and 2 levels. Other graphs were constructed to look at the nutrient relationships between lagoon locations 5 and 6 and stream 3. Correlation values were determined to examine relationships between nutrient levels in the stream and the lagoon.

It is not certain exactly how much of an impact the streams have on the Basin Head lagoon but it is clear that they do have an effect. Levels for phosphate and nitrate at certain locations within the lagoon are well above the ocean levels, which would be expected in the lagoon. The high levels are found mainly at locations in the lagoon that are close to the stream outlets. In order to examine this relationship more closely nitrate levels for lagoon locations 5 and 6 were graphed against levels found in stream 3 (Figure 4.26). Locations 5 and 6 were the only ones examined for nitrate, as these were the two where lagoon levels were well above ocean levels.



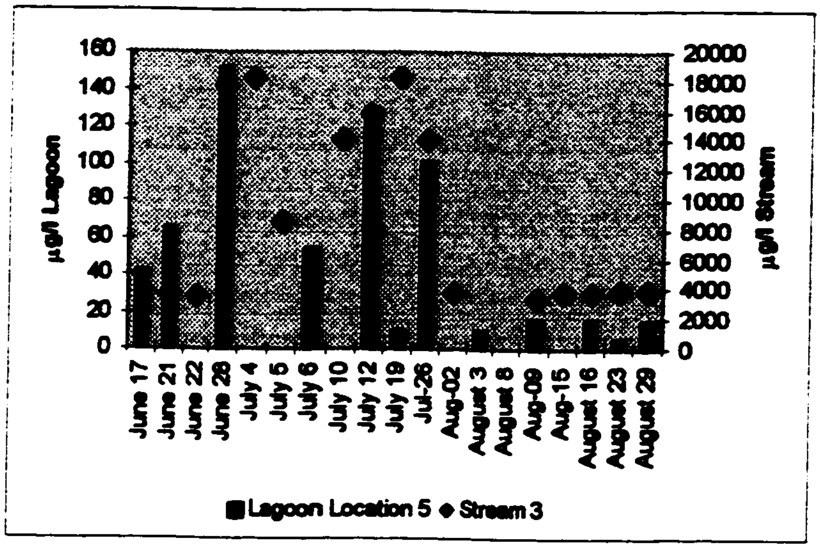


Figure 4.26 Nitrate - Stream Concentration vs. Lagoon Concentration

All sampling days were graphed but for discussion of the stream effects, only the days where sampling was conducted on both the stream and lagoon will be examined. Location 5 shows a correlation value of 0.63 when compared to stream 3 levels. This means that there is a relationship between the values on stream 3 and location 5. Unfortunately, the correlation found for location 6 is – 0.29, which indicates no relationship between values in the stream and lagoon. It is interesting to note that when location 5 has high values of nitrate location 6 values are low and the opposite is true when location 6 has high values. There is some influence from the streams on lagoon nitrate levels but there must be other sources entering the lagoon or biological reasons for increased levels of nitrate in the main basin. The dominant circulation pattern within the lagoon appears to be tidal driven. There is an increased population of Ulva located at Location 6.

Phosphate levels within the lagoon were mainly above the ocean nutrient level. This was most evident around locations 1 and 2 where streams 1 and 2 flow into the lagoon. Phosphate levels within the lagoon at these locations were graphed against both stream 1 and 2 (Figure 4.27). For lagoon location 1 there was very little correlation with the streams, 0.13 with stream 1 and 0.31 with stream 2. Part of the reasoning in this may be with the effects of the huge population growth of Ulva in the area. Location 2 and the two streams had a better correlation, with 0.48 for stream 1 and 0.80 for stream 2. Once again, it is believed that the streams are having an impact on the lagoon, especially where streams enter the lagoon. There are also other sources that are affecting lagoon nutrient concentration levels that may involve biological factors or groundwater transport. Also, release of phosphorus bound to sediment may influence increases of phosphate levels.

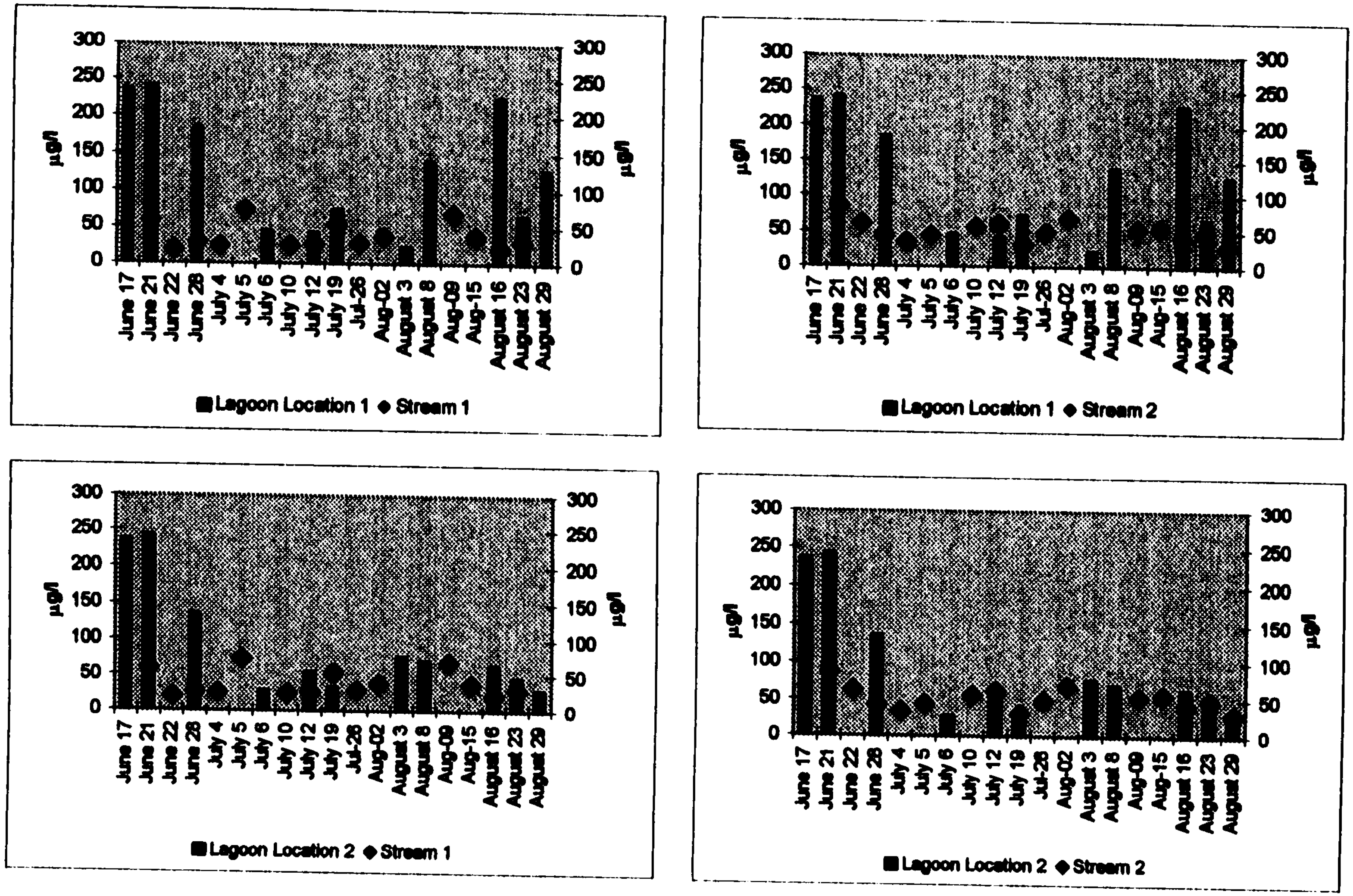
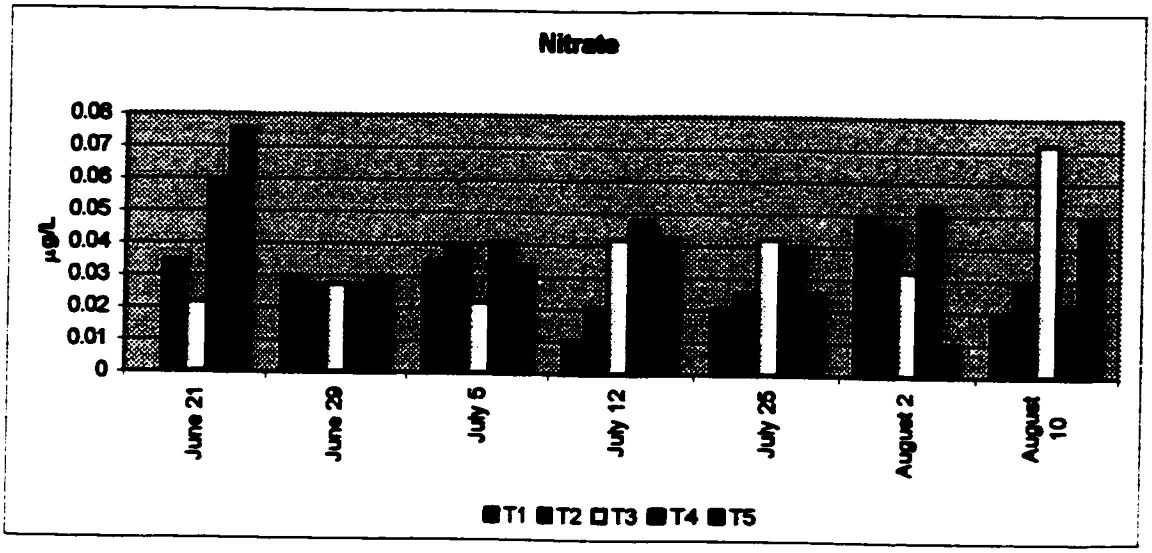


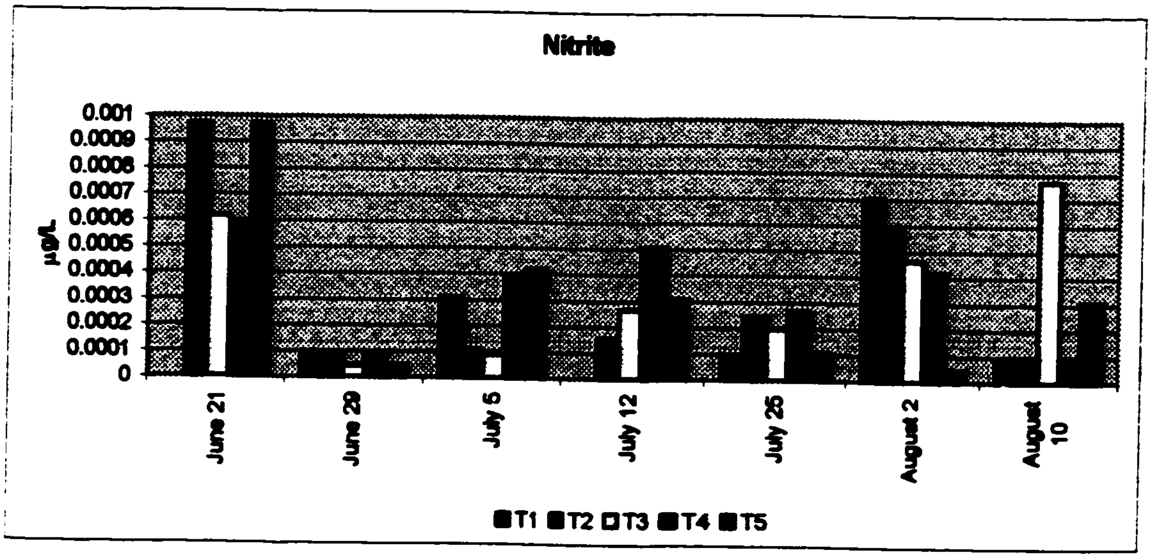
Figure 4.27 Phosphate – Stream Concentration vs. Lagoon Concentration

4.11 <u>1979 Lagoon Chemistry</u>

McCurdy (1979) conducted a study that examined the ecology of the Basin Head Lagoon. He was examining the differences between Basin Head and South Lake, which is nearby and surrounded by similar land activity. South Lake is larger and deeper and conditions of the water are less variable. The study attempted to determine why Irish Moss was present in Basin Head but not South Lake. In the processes completing this study he collected water samples within the lagoon to examine phosphate, nitrate, and nitrite levels. His results were expressed in μg – atoms/l and therefore were converted to $\mu g/l$ by multiplying by 1/atomic weight for each nutrient. The limited nutrient data collected was graphed to show levels within the lagoon during 1979. The levels from 1979 were compared to levels determined during the 2000 study to compare chemistry of the lagoon over the past 21 years.

Most of the sampling for nutrients took place on the transect lines but there are values for sample stations 3, 4, 5, and 6 for July 5, 1979 (refer to Figure 3.5). It is not apparent from the document why sampling at stations 1 to 6 only took place on one day. Transects 1 –5 are all close to sampling station 2 which will be able to provide insight as to how levels have changed compared to those obtained during the field season of this study. Figures 4.28 and 4.29 show the nutrient levels obtained from the 1979 study.





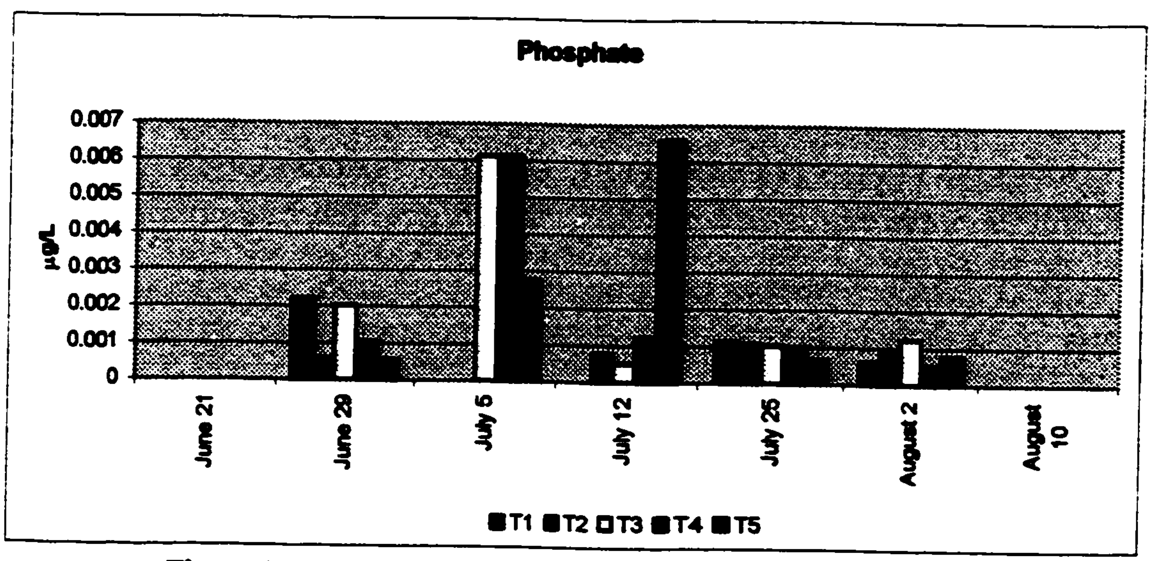


Figure 4.28 Nutrient Levels Obtained During Summer 1979

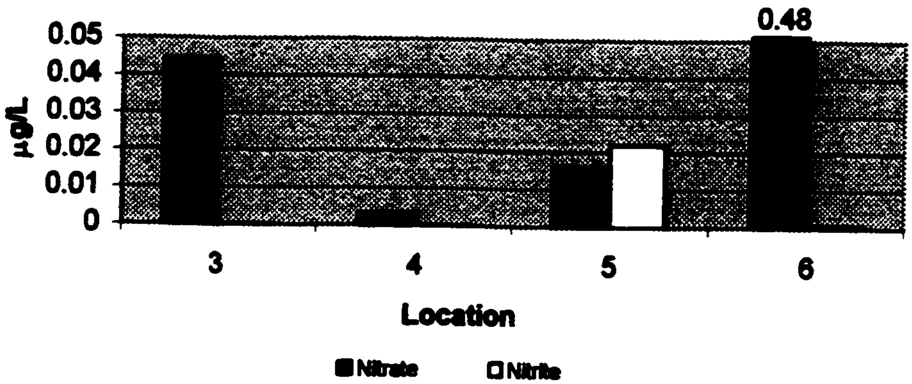


Figure 4.29 Nutrient Levels at Sample Stations, July 5, 1979

The nutrient levels obtained in 1979 are much lower than the ones obtained in the summer of 2000. The highest nitrate level was found to be 0.076 µg/l while the study conducted in 2000 had levels around 50 to 100 µg/l, with some days reaching over 1000 µg/l. Nitrite levels show the same differences with ranges reaching 0.0009 µg/l in 1979 to values of 5 – 23 µg/l in 2000. Phosphate values were anywhere from 0.001 –0.006 µg/l in 1979 but in 2000 these values ranged from 10 – 242 µg/l. The values taken on July 5th also show that there has been an increase of levels of nitrate and nitrite from 1979 up to 2000.

The nutrient analysis in 1979 followed the Strickland and Parsons (1972) method for analysis, this method closely resembles the ones used for the 2000 study. Therefore, since there is no first hand knowledge of the nutrient analysis it must be assumed that analysis was completed correctly and that the values obtained were correct. The range of differences that were found between 1979 and 2000 are extreme and therefore questionable. If true, it suggests that there has been a huge change in the levels of nutrients in the lagoon. This may be explained by use of fertilizer through farming activities over the Basin Head watershed but can't be confirmed as this knowledge is unknown and was out of the scope for this study. Digital information obtain from the Prince Edward Island Department of Fisheries, Aquaculture and Environment does show that farming activity has increased from 7.91km^2 in 1996 to 9.37km^2 in 2000 within the Basin Head watershed. This information was collected through air photo interpretation. Statistics obtained from the Government of Prince Edward Island (2002) shows fertilizer sales for Prince Edward Island had increased from 41,192 tons in 1990 to 84,255 tons in 1998. The amount of increase that this represents around Basin Head is unknown.

4.12 Basin Head Watershed Compared to Areas on PEI

In 1999 a Water Quality Interpretive Report was produced for Canada – Prince Edward Island Water Annex (Somers *et al.*, 1999). This report examined current conditions and some long-term trends in water quality in five watersheds around Prince Edward Island. The report examined surface freshwater nutrient conditions as well as some of the marine nutrient conditions from estuaries around Prince Edward Island. The levels found in the Basin Head watershed were compared to levels found in areas around Prince Edward Island to determine how the Basin Head area compared to the rest of Prince Edward Island (Table 4.11 – 4.12).

µg/l	PEI Averages	Basin Head		
		Stream 1	Stream 2	Stream 3
Nitrate	6900	11 100	9400	8800
Phosphate	27	40	50	50
Total Phosphorus	49	60	100	70

Table 4.11 Fresh Water Nutrient Averages for PEI and Basin Head

µg/l	PEI Averages	Basin Head
Nitrate	380	87 (some levels reached 700 & 1400)
Phosphate		59
Total Phosphorus	40	60

Table 4.12 Lagoon and Estuarine Nutrient Averages for PEI and Basin Head

The values found in Basin Head are higher than the PEI averages for the fresh water systems. The numbers for nitrate levels show that on average Basin Head is below the averages found in other areas. In the Basin Head lagoon the nitrate values seems low but this may be deceiving as it is an average lagoon concentration. During July and August within Basin Head nitrate levels were found to reach 700 – 1400 µg/l.

4.13 Summary

This chapter examined the conditions that existed at Basin Head Lagoon during the summer of 2000. The overall climate of the area from past years was shown in order to place the summer of 2000 in comparison to other years. It is apparent that rainfall levels were down compared to previous years. Daily climate data were unavailable for the Basin Head area; therefore the next closest areas were selected for comparison in the hope that they would have a similar relationship of rainfall characteristics. This was not the case as it was determined that the rainfall in the Basin Head area is dominated by localized events. Therefore, daily precipitation values could not be used from other areas to represent rainfall at Basin Head. The only data from Basin Head were the precipitation data collected from the rain gauges during significant rainfall events throughout the summer.

The hydrology of the three studied streams was also examined showing discharge and statistics on each. The statistics were completed to show the high discharge of water from stream 3 as compared to the other streams.

The physical properties of the lagoon were examined as this had not been done before and would be good baseline information for the pending management plan. Tidal levels were monitored and a corrected bathymetric map of the lagoon was produced. This was used to produce estimates of the volume of the lagoon at different tidal levels. This information along with salinity levels in and around the lagoon were vital in calculating the hydrologic residence time for the Basin Head Lagoon. The residence time was calculated during six days of the study period and it was determined that residence time for the lagoon was short, from 0.73 – 6.8 days. Therefore turnover of nutrients within the lagoon would be assumed to be rapid and ocean levels would dominate.

The chemistry of both the streams and the lagoon were an important part of the study and were examined in detail. Concentrations and mass flux of SRP, TP, Nitrate, and Nitrite were analyzed for each of the three streams along with a 24- hour sampling survey of stream 3 characteristics. The lagoon chemistry examined concentrations at six locations and the differences throughout. Information was obtained from the Department of Fisheries and Oceans on the ocean nutrient levels for phosphate, nitrate, and nitrite. These nutrient levels were then compared to levels found within the lagoon to determine how much influence the streams might have on lagoon chemistry. It was determined that the streams have an impact on the lagoon chemistry but the extent was not clear. Lagoon locations 5 and 6, within the main basin, were most affected by nitrate while locations 1 and 2, within the arm, were most affected by phosphate. Chemistry information from the

2000 season was also compared to values determined during a study completed in 1979. It was found that nutrient concentrations have increased significantly over the past 20 years leading to questions in reliability of the data.

The Basin Head streams and lagoon had nutrient values that were higher than the average values found in marine environments around Prince Edward Island. This showed the important role of nutrients within the Basin Head watershed.

The next step is to determine what conclusions can be made about the Basin Head Lagoon environment. This includes determining what the information means for the development of the management plan for Basin Head.

CHAPTER 5

5 Conclusion

Stream and lagoon water sampling were conducted at Basin Head in June, July, and August 2000 in order to examine and monitor nutrient and suspended solid levels within the streams and lagoon. Sample collection was also conducted during rainfall events to determine the impact of rain on nutrient levels and stream discharge rates. A bathymetry map of the lagoon was produced from collected depth measurements to assist in obtaining a hydrologic residence time for the lagoon. Ocean nutrient levels were compared to nutrient levels obtained within the lagoon. The nutrient levels obtained during a study conducted earlier (McCurdy, 1979) were compared to lagoon nutrient levels obtained during the summer of 2000. The Basin Head area nutrient levels were compared to other areas around Prince Edward Island to determine if any relationship existed.

The main objective of the project was to examine the impact, if any, that the streams had on the nutrient levels found within the lagoon. This was completed by examining the levels of nutrients (phosphate, total phosphorus, nitrate, and nitrite) being exported from the Basin Head watershed, through runoff, into the Basin Head Lagoon. Knowledge of stream impacts on the lagoon would aid in the completion of the management plan as specific controls could be addressed according to the situation.

The weather observed at Basin Head during the summer of 2000 had temperatures that were near normal while precipitation was below normal levels. Rainfall obtained at Basin Head showed five days of significant rainfall. This was collected manually through the use of rain gauges. Environment Canada had daily rainfall monitoring stations set up throughout Prince Edward Island. The closest stations to Basin Head were located at Bangor and Monticello. Visually there appeared to be little correlation between the locations. In order to examine any relationship between rainfall at the other locations and conditions at Basin Head regression analysis was performed on rainfall and discharge levels of the streams. The r^2 values obtained were in the order of 0.12 to 0.41 showing that no relationship existed. Rainfall in the Basin Head area appears to be a very localized phenomenon. Daily rainfall measurements recorded by Environment Canada were found not useful for the Basin Head area. Basin Head experienced low levels of rainfall during the summer of 2000 therefore it is important to keep in mind that results may be different during an average year.

Discharge measurements of the three streams were calculated and graphed for the summer. Stream 3 had the highest levels of discharge, which was expected as the stream was larger than the other two and had a larger watershed drainage area (4.38 km^2). The highest levels of discharge for the streams appeared on July 4th and 5th. These days had noted levels of rainfall. Rainfall data collected at Basin Head were graphed against discharge levels of the three streams. During early July, three days of rainfall corresponded to high discharge levels but this was not the case for the two rainfall events in August. On these days rainfall did not produce high discharge levels. There was a long period without rain before these days, leading one to believe that this rain was absorbed by the dry farmland before it became runoff for the streams. Another notable aspect of the rainfall during the summer of 2000 was that for nearly all events it was a long and steady rain and not heavy precipitation. August 2nd and 29th were days where stream three had high discharge levels but no rainfall occurred. This leads to the belief that there was another source of water emptying into the stream.

Suspended solids were measured within the three streams and graphed against stream discharge to examine any relationship. No relationship existed between the two variables. This may partly be explained by riparian buffer zones being implemented through tree and vegetation planting along the streams during the summer of 1999. Sediment loads were calculated for all three streams and levels were low throughout the entire sampling period. This leads one to believe that sediment erosion is not as large a problem as it appears to be on the rest of Prince Edward Island.

A bathymetry map of the lagoon was produced to obtain lagoon volume levels throughout the study period and to aid in the calculation of hydrologic residence time. The volume of the lagoon at low tide is approximately 2.54×10^5 m^3, high tide is approximately 10.39×10^5 m^3, and average lagoon volume is approximately 8.48×10^5 m^3. The hydrologic residence time of the lagoon was calculated to be between 0.73 and 6.82 days. The mean residence time was calculated as 2 days. Thus, it was determined that the levels within the lagoon should be at concentrations close to those of the adjacent ocean.

The stream chemistry was examined throughout the field season and the nutrient concentrations of nitrate, nitrite, phosphate, and total phosphorus were obtained. These levels were graphed along with discharge to see if any relationship existed. For the most part, no pattern emerged that related stream discharge to phosphate concentrations. Days with high rainfall showed the highest levels of total phosphorus, but it does not appear to be related to days of high sediment load. Nitrate concentrations show no relationship to discharge but all three streams show a pattern of low concentrations at the beginning and end of the summer and high concentrations during mid-summer. This could be attributed to stages of nutrient uptake and growth of agricultural plants. Nitrite levels remain stable throughout the entire study period. Mass flux of all nutrients was calculated to show the amount released from the streams into the lagoon at specific sampling periods. As stream three had the largest discharge levels it is only normal that stream three would also have the highest mass flux of nutrients. The highest amounts of phosphate occur on July 5th for streams one and two, which corresponds to days of rainfall. Total phosphorus values appear high on July 5th and 19th. The flux of nitrate again appears to be high in the middle of the season. Amounts of nitrite remain relatively low for both stream 1 and 2 with values being slightly elevated for stream 3.

The 24-hour examination of stream 3 shows more information about what is ongoing on a continuous basis. The mass flux of nutrient levels was examined and all showed a similar pattern of a peak in flux from 2:00 AM to 5:00 AM. This raises questions about what is happening during this time. Precautions were taken to ensure tidal influence was not occurring near the weir placement through measurement of salinity levels during weir installation. As an additional check tide levels were examined to ensure large tidal levels were not being experienced during sampling. This leads one to believe that there may have been an external source that was contributing these increased nutrient levels within the stream during these times. Stream three did have an outfall located nearby which may have been contributing additional water to the stream but this can not be confirmed as it was not monitored to see if any water was ever discharged from it. Discharge levels were also graphed against suspended solids but no relationship appeared to exist. Stream nutrient concentrations obtained within Basin Head can be compared to concentration levels deemed to be suitable for freshwater environments. For phosphate this level is 50 μg/l in order to stop long-term eutrophication (Dunne and Leopold, 1978). For total phosphorus the USEPA (1986) has set a level of 50 μg/l in order to control eutrophication. Nitrate levels are rarely more than 5000 μg/l and often less than 1000 μg/l (McNeely *et al.*, 1979, OME, 1981). Canadian guidelines for nitrite levels are set at 60 μg/l (CCREM, 1987). The average levels of phosphate on streams 1, 2, and 3 were 38.1, 51.8, and 46.6 μg/l respectively. Stream 2 and 3 should be monitored carefully as the values were very close to the suggested limit. The average levels of total phosphorus on streams 1, 2, and 3 were 55.2, 98.3, and 70.3 μg/l respectively. All are above the recommended guidelines with stream 2 being extremely high. Nitrate levels on streams 1, 2, and 3 were 11 077.4, 9367, and 8773 respectively. All levels are well above the suggested level of 5000 μg/l. Nitrite levels on all three streams were well below the guideline of 60 μg/l.

The lagoon levels for phosphate, nitrate, and nitrite were graphed for the study. Phosphate levels were high for location 1 and 2 during June and August. They remained fairly stable throughout for the rest of the lagoon. The nitrate and nitrite levels were high for the end of July and August at location 6 while all other locations remained fairly stable. Since it was previously determined through calculation of residence time that lagoon concentrations should closely resemble ocean concentrations these two levels were graphed to examine the relationship. Ocean nutrient levels obtained for nitrate and phosphate for the months of June, July, and August of 2000 showed little variation. Therefore, the levels were graphed and a trend line imposed to show average level throughout the study season. There were obvious occasions where lagoon levels far exceeded ocean nutrient concentrations for both nitrate and phosphate. Location 5 and 6 seemed to be the problem regarding nitrate levels while location 1 and 2 were the problem with phosphate levels. The high levels of phosphate within the lagoon could be attributed to the release of phosphate particles from suspended solids.

From the data collected and subsequent analysis it is apparent that the streams do have an impact on the nutrient levels found within the lagoon. The level to which the streams are influencing the lagoon can't be determined with certainty. More information should be collected about the groundwater contribution of nutrients to the lagoon.

When compared to the 1979 study conducted by McCurdy (1979) all nutrient levels in 2000 were well above those in 1979. The report produced by Somers *et al.* (1999) did note a trend of increasing nutrient levels in areas around Prince Edward Island but none of the magnitude experienced at Basin Head. This raises questions about the reliability of the data from the earlier study.

Nutrient levels found within Basin Head were compared to other nutrient information collected on streams and estuaries around Prince Edward Island. The values found in Basin Head are higher than the PEI averages for the fresh water systems. In the lagoon the nitrate values seems low but this may be deceiving as it is an average lagoon concentration. During July and August within Basin Head nitrate levels were found to reach 700 – 1400 μg/l. Overall, nutrient concentrations within the freshwater environment of Basin Head are supplying higher than average concentrations of nutrients to the lagoon.

Table 5.1 below summarizes the nutrient concentration levels found in the Basin Head Lagoon over time, along with 2000 nutrient levels on the freshwater stream. These are compared to the Prince Edward Island averages for freshwater and estuarine and lagoon environments. The ocean concentration levels and freshwater nutrient standards found in literature are also included for ease of comparison.

µg/l		Phosphate	Nitrate	Nitrite	Total Phosphorus
1979 Lagoon		0.004	0.076	0.0009	
2000 Lagoon		59	87 (levels reached 700 & 1400)	5	60
PEI ave. for Estuaries and Lagoon			380		40
Ocean		27	94		
2000 Streams	1	40	11 100		60
	2	50	9400		100
	3	50	8800		70
PEI ave. Streams		27	6500		49
Standards for Freshwater		50	5000		50

Table 5.1 Summary Table of Concentration Levels

This shows the dramatic increase of nutrients within the lagoon from 1979 to 2000 which raises questions about the reliability of the data obtained in 1979. Compared to other areas around Prince Edward Island the lagoon is close to levels for total phosphorus. The nitrate data may be misleading for the Basin Head Area as average concentrations were low but at times reached levels well above the Prince Edward Island averages. The stream nutrient concentrations are close and in some cases above standard levels found in literature.

From the nutrient study conducted during the summer of 2000 it is obvious that the surrounding agricultural environment is impacting the Basin Head lagoon. The management plan that will be designed when the area becomes a Marine Protected Area should reflect this and monitoring of the streams should be ongoing to identify any changes within the system. The Prince Edward Island government is doing their part to help in the management process by restricting the farming practices across the province. According to an article in *The Toronto Star* (Keeping the Fish Alive, 2001), the province was putting forward legislation to have mandatory crop rotation every three years. This means that the planting of potatoes and other row crops can only occur once every three years on a plot of land. This legislation was put forth due to the increasing use of chemicals in farming and the huge losses of topsoil to the surrounding waters. This management process will also provide help in the Basin Head Area. The legislation is called the Agricultural Crop Rotation Act and was put into force on April 6th 2002. If an appropriate management plan can show that necessary measures will be taken, a field can be exempt from the three-year rotation.

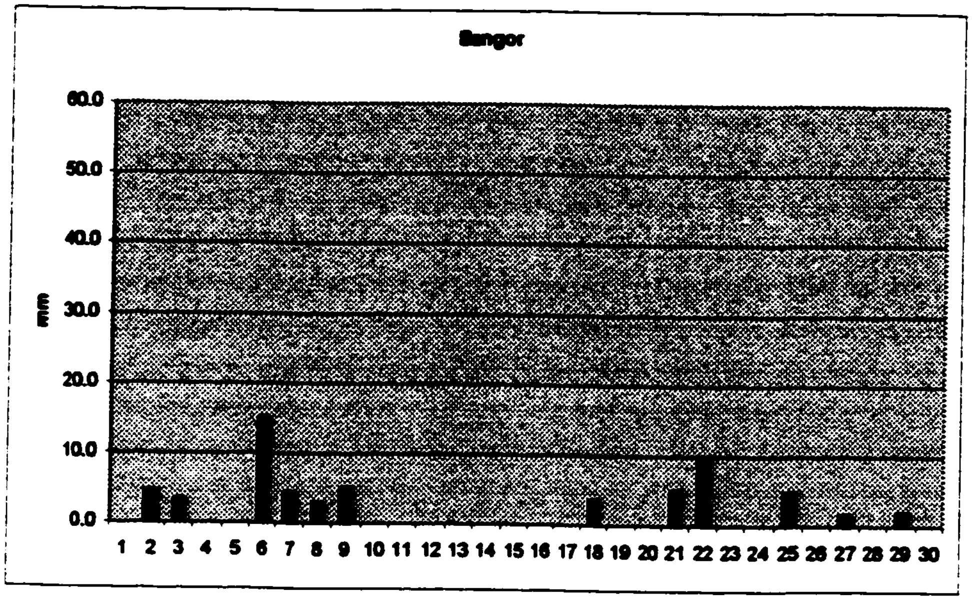
There has been specific action within the Basin Head watershed to try and help with runoff, such as the upkeep of buffer zones surrounding streams and contour tillage on some farmland. From the results gathered during the summer of 2000 it is obvious that more needs to be done. Increased fertilizer management in the area should be considered. As suggested in the report on P.E.I. water quality (Somers *et al.*, 1999) it is not likely that reduction of phosphorus or nitrogen alone will work. It may be that both have to be reduced so as not to alter the ratio of nutrients in the water. This could be difficult as the methods used to reduce the levels may not be the same, as nitrate is soluble in water and phosphorus is largely bound to sediment. Therefore, measures such as erosion control may be more useful for phosphorus management from runoff and fertilizer control may be more useful for nitrogen management. The key management challenges may be identifying and satisfying the interests of all stakeholders involved. The stakeholders include the farmers of the area, members of the tourism industry, residents in the area, biologists concerned with Irish Moss, and government agencies. Not everyone will want to see Basin Head become a Marine Protected Area. Farmers may get more attention about nutrients being exported into the surrounding lagoon. Also, the increased publicity surrounding the area will bring more tourism to Basin Head. This may be favourable to the merchants in the area but the residents may see this increased traffic as negative. The management plan derived for the Basin Head area will have to consider not only the physical properties of the environment but the socio-economic factors involved in defining Basin Head as a Marine Protected Area.

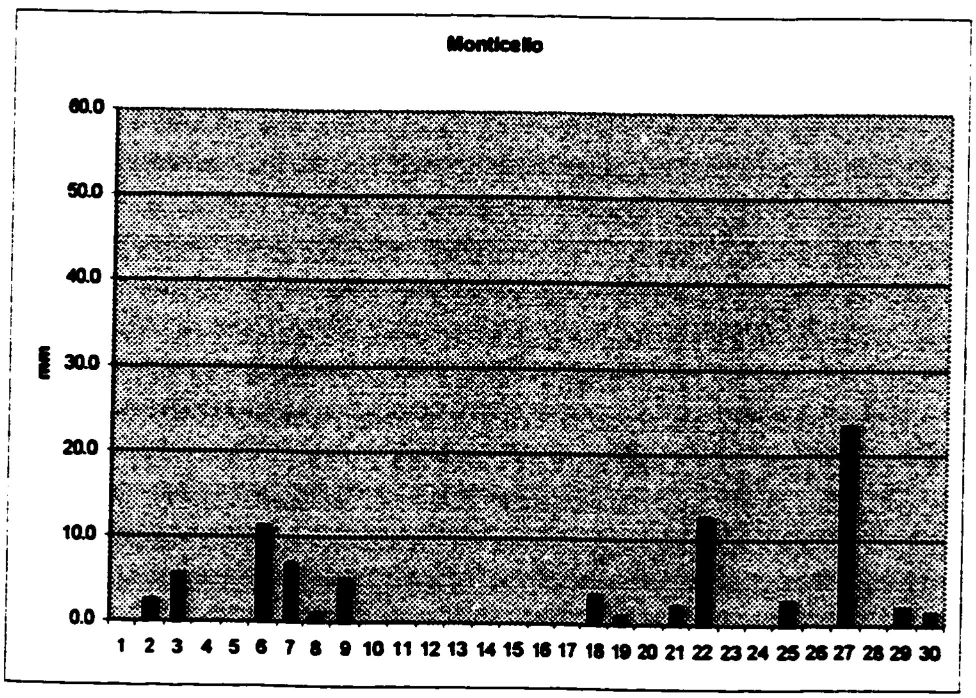
5.1 Recommendations and Future Research

The data collected at Basin Head during the summer of 2000 gave an idea of what is happening in the stream and lagoon system that will be very useful as baseline information for the area. In order to get a more detailed look at what processes are occurring in the area more research needs to be completed. A study that monitors continuous conditions for rainfall, conditions within the streams, and lagoon conditions would give a much better idea of ongoing conditions than instantaneous sampling. The use of automated samplers could provide continuous data, which would also mean more samples to be analyzed giving a clearer picture. Since this area has no previous record of stream chemistry or runoff effects it is suggested that in the beginning the more information the better. A study examining stream conditions just before spring thaw would give details about nutrient transport during baseline flow. A study period lasting one year in length would give a complete picture of conditions throughout the year. Precipitation measurements within the lagoon would be useful to assess the amount of nutrients from rainfall. It is suggested that a meteorological station be set up in the Basin Head area to give more localized information. It would also be useful to get information on farming practices and fertilizer use on individual farms within the watershed. Closer attention should be given to stream three to identify if peaks of discharge and nutrients in the early hours are a regular occurrence. A closer examination of flow pathways other than surface flow would give an overall picture of where nutrients are coming from and better management practices could be implemented. These would include groundwater flow and outflows that transport water to the lagoon. Also, looking at the water flowing through the dunes and its ecology will help to obtain an overall picture of the nutrient budget of the Basin Head Lagoon. The Irish Moss within Basin Head has been studied in previous years. The significance of the Irish Moss to the water chemistry of the lagoon and the impacts of the lagoon chemistry on the growth of Irish Moss would be useful knowledge to sustain the growth within Basin Head. Other research that would be useful for the Basin Head area includes analysis of historical air photos to identify changes in the watershed area over time along with oral histories from farmers and residents in the area on changes in farming practices.

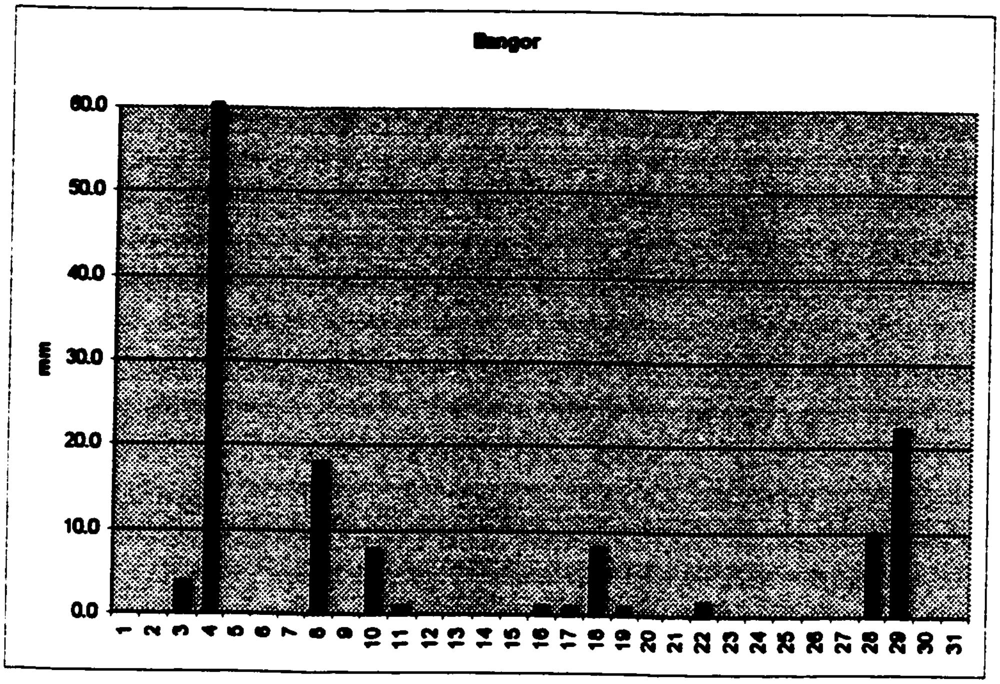
APPENDIX A

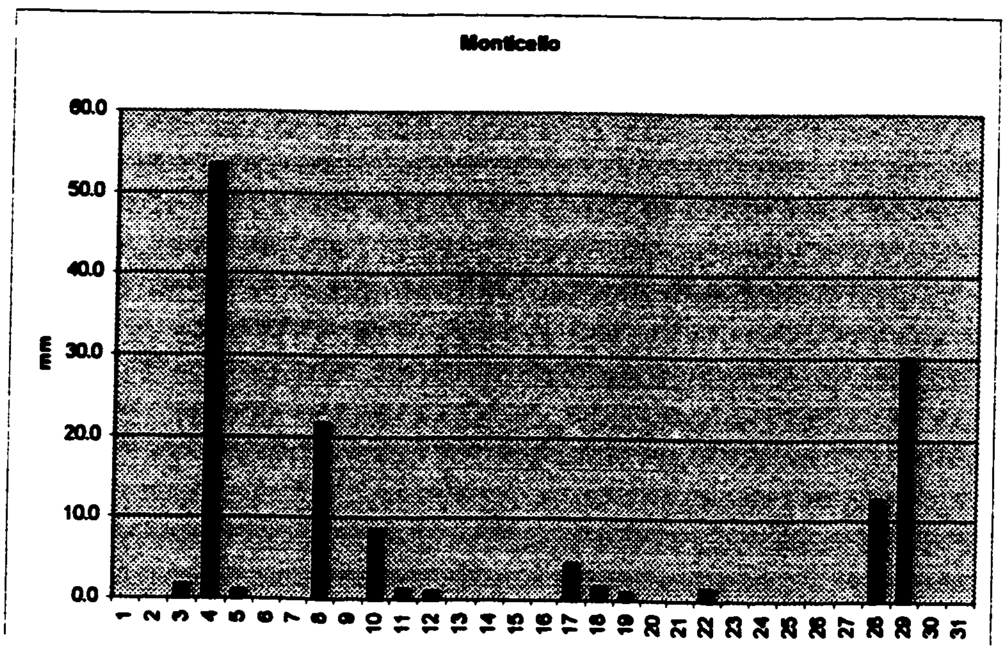
Summer 2000 Rainfall Measurements



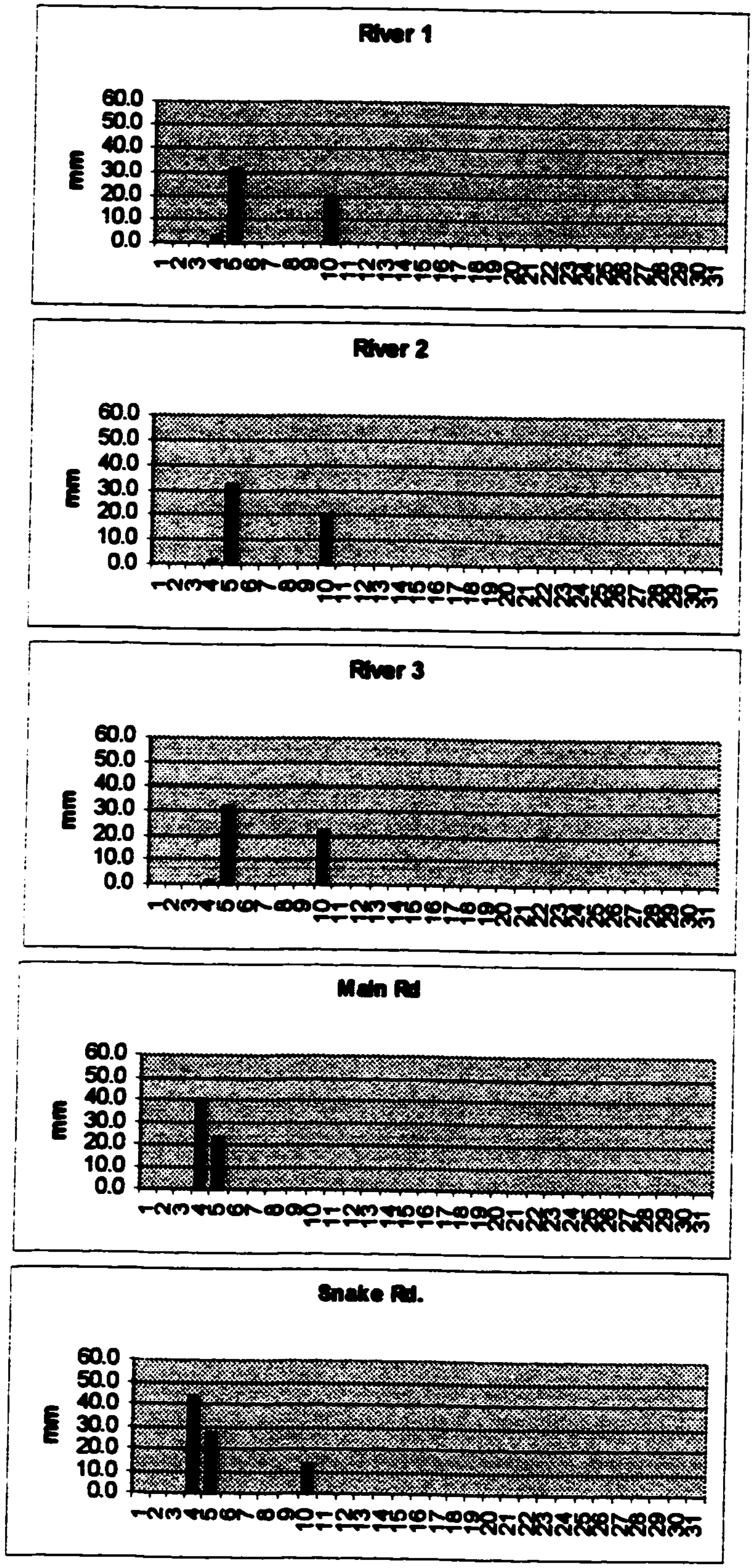


Rainfall Measurements For June

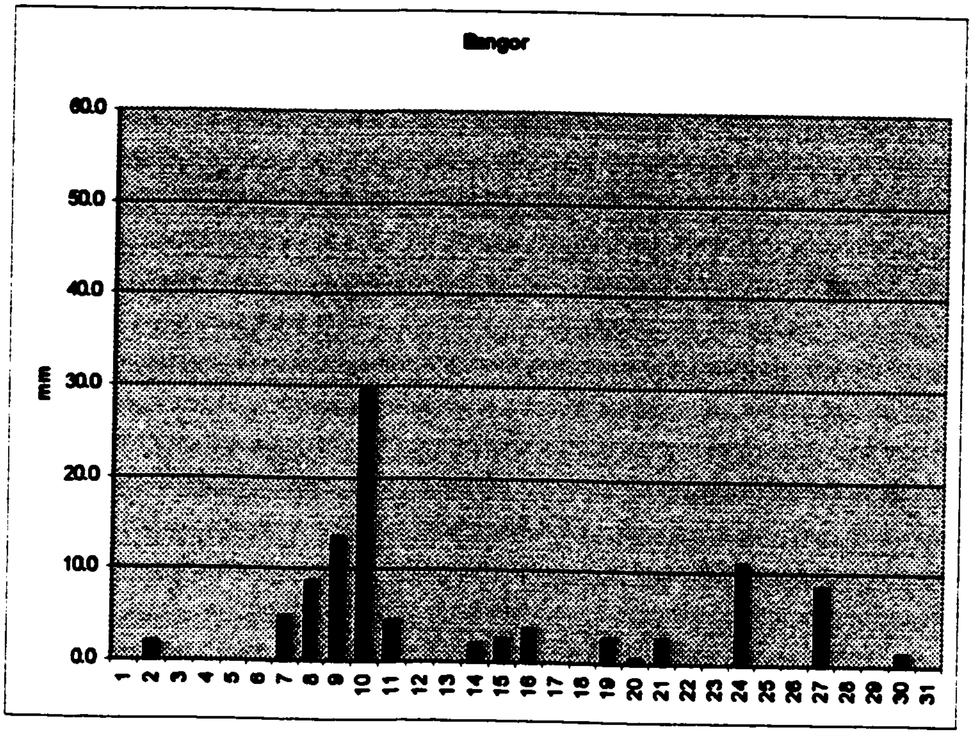


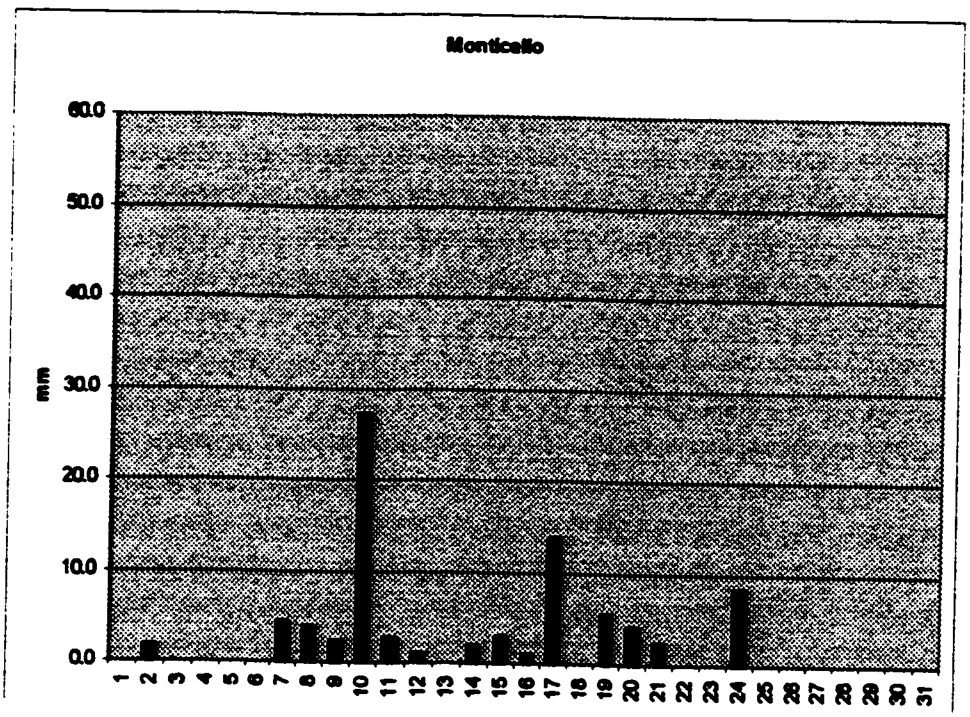


Rainfall Measurements For July

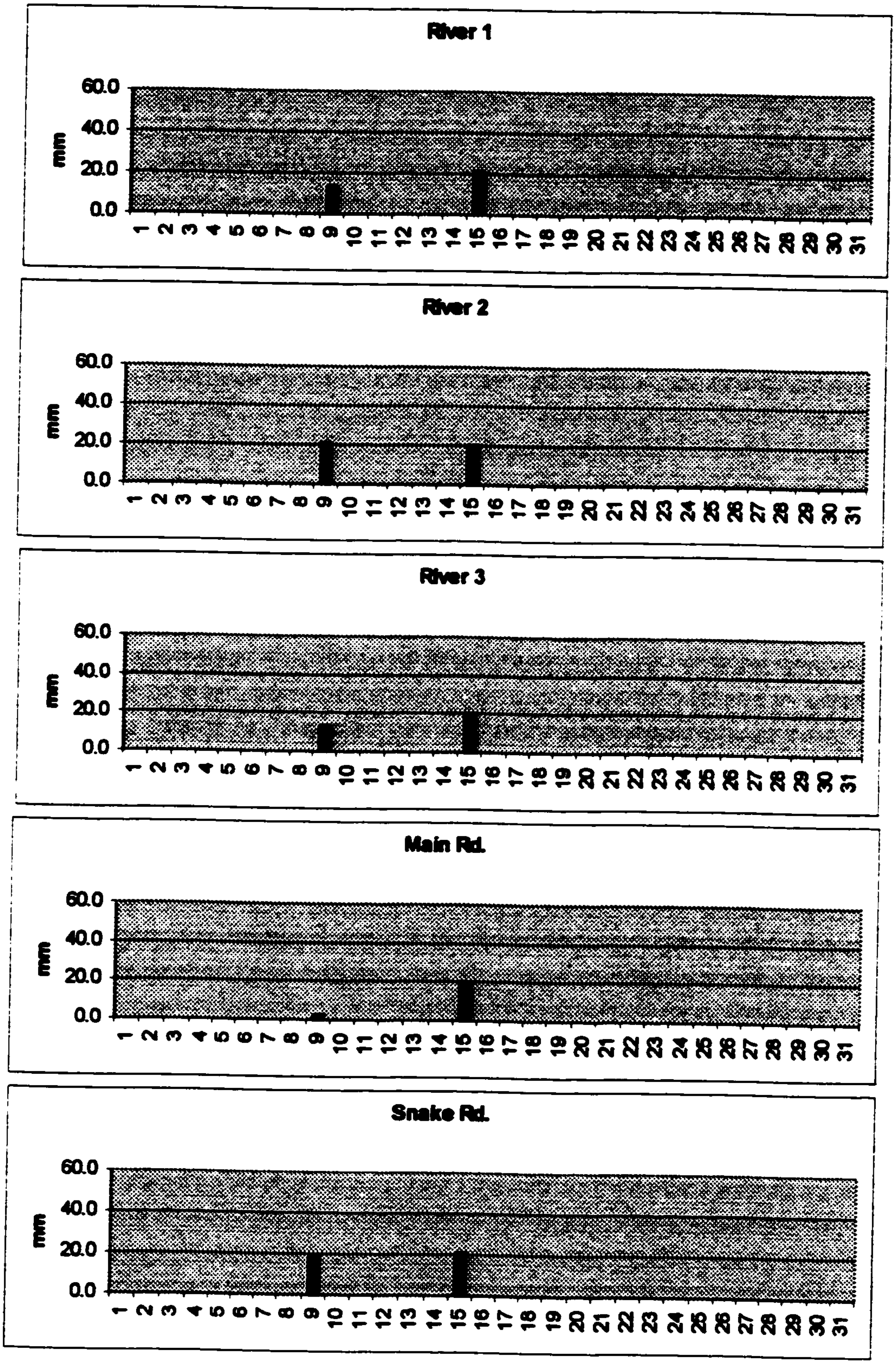


July Rainfall For Basin Head





Rainfall Measurements For August



August Rainfall For Basin Head

APPENDIX B

Salinity Levels

Ocean Salinity

Approximately 300 m from lagoon outlet at the center and to the left and right

Lagoon Salinity

Sample Locations

July 26, 2000

	Left		Center		Right		1	2	3	4	5	6
Time:	9:53 AM	2:50 PM	9:50 AM	2:46 PM	9:45 AM	2:42 PM				11:00 AM	10:10 AM	10:37 AM
Depth (M):	0.68	0.72	0.57	0.89	0.5	0.7				0.235	0.195	0.28
Salinity:	30ppm	29ppm	30ppm	27ppm	30ppm	26ppm				24ppm	27ppm	15ppm

August 3, 2000

	Left		Center		Right		1	2	3	4	5	6
Time:	12:25 PM	2:53 PM	12:23 PM	2:49 PM	12:20 PM	2:45 PM	12:56 PM	1:45 PM	2:01 PM	2:10 PM	2:20 PM	2:30 PM
Depth (M):	1.29	1.03	1.31	1.08	1.28	0.63	0.88	0.94	0.945	1.04	0.865	0.94
Salinity:	31ppm	30ppm	32ppm	30ppm	31ppm	30ppm	24ppm	30ppm	30ppm	28ppm	30ppm	27ppm

August 8, 2000

	Left		Center		Right		1	2	3	4	5	6
Time:	5:40 PM	7:12 PM	5:39 PM	7:11 PM	5:37 PM	7:09 PM	6:20 PM	6:40 PM	6:55 PM			
Depth (M):	1	0.98	1.3	1.27	0.97	0.81	0.52	0.585	0.77			
Salinity:	30ppm	31ppm	30ppm	30ppm	30ppm	31ppm	22ppm	25ppm	28ppm			

August 9, 2000

	Left		Center		Right		1	2	3	4	5	6
Time:	1:14 PM	2:19 PM	1:12 PM	2:18 PM	1:10 PM	2:16 PM				1:33 PM	1:41 PM	2:54 PM
Depth (M):	0.58	0.74	0.8	1.1	0.68	0.69				0.49	0.25	0.48
Salinity:	29ppm	30ppm	28ppm	30ppm	30ppm	31ppm				28ppm	28ppm	12ppm

August 23, 2000

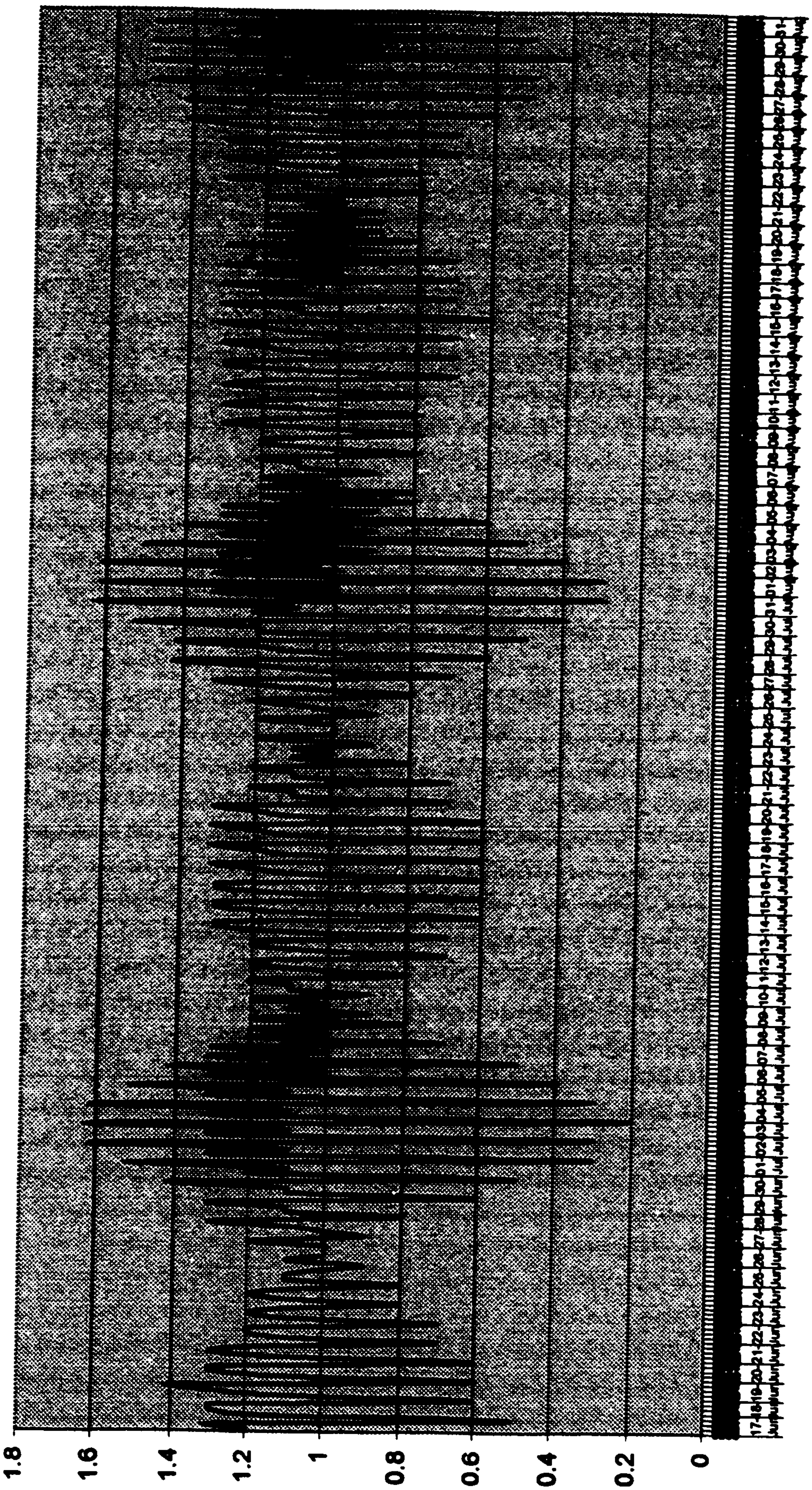
	Left		Center		Right		1	2	3	4	5	6
Time:	2:37 PM	5:03 PM	2:35 PM	5:00 PM	2:32 PM	4:58 PM	3:14 PM	3:45 PM	4:00 PM	4:08 PM	4:16 PM	4:30 PM
Depth (M):	1.03	1.1	1.1	1.4	0.84	1	0.23	0.52	0.66	0.8	0.76	0.8
Salinity:	30ppm	30ppm	30ppm	30ppm	29ppm	30ppm	20ppm	22ppm	28ppm	25ppm	30ppm	8ppm

August 29, 2000

	Left		Center		Right		1	2	3	4	5	6
Time:	10:45 AM	1:04 PM	10:42 AM	1:02 PM	10:40 AM	1:00 PM	11:20 AM	11:43 AM	11:55 AM	12:04 PM	12:21 PM	12:30 PM
Depth (M):	1.27	1.15	1.4	1.1	1.04	0.73	0.9	0.96	1.03	0.94	0.74	0.88
Salinity:	32ppm	30ppm	33ppm	30ppm	34ppm	30ppm	24ppm	28ppm	30ppm	30ppm	30ppm	26ppm

APPENDIX C

Tidal Information



Fisheries and Oceans Canada, 2000

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